EARTH RESOURCES TECHNOLOGY SATELLITE FINAL REPORT

6. RELIABILITY PROGRAM PLAN

PREPARED FOR

GODDARD SPACE FLIGHT CENTER
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

UNDER CONTRACT NAS5-11260

TRW SYSTEMS GROUP

IBM FEDERAL SYSTEMS DIVISION

Itek OPTICAL SYSTEMS DIVISION

EARTH RESOURCES TECHNOLOGY SATELLITE

FINAL REPORT

Volume 6 Reliability Program Plan

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prepared for

National Aeronautics and Space Administration
Goddard Space Flight Center

Contract NAS5-11260

Item 5a

TRW Systems Group
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ROAD MAP

REVISIONS AND ADDITIONS TO FEBRUARY SUBMITTAL

Subsequent to the 90 day proposal submittal this volume has been expanded or changed to include system or GDHS inputs To facilitate NASA review, additional or changed information appears only on yellow pages The changes on each yellow page, identified by shading in the area of change, are on the pages listed below.

Page	Change
1-1	Software included
1-2	Expanded reliability requirements
1-3	Included reliability documentation
2-4	Included software testing
2-7	Added software requirements
2-10	Included software test tools and added to subcontractor and supplier control
2-11	Government furnished property control included
3-1	Software requirements included
3-3	Software requirements included
3-4	Clarification and software requirements included
3-5	Software requirements included
3-8	Software requirements included
3-10	Software requirements and references included
3-13	Clarification and GDHS requirement included
3-15	Traceability included
4-1	Software description included
4-2	Software description included
4-3	Software testing included
D-1	Reliability assessment approach included
E-1	GDHS Subcontractor requirements Appendix added

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CHAPTER I: INTRODUCTION

1A100 Scope

The NASA/GSFC approved OGO reliability program revised to meet the ERTS requirements is presented in this document. The plan covers all aspects of reliability for the phase D contract. The plan is written in compliance with NPC 250-1 but is structured in accordance with the draft copy of the new NASA "Reliability Program Provisions for Space System Contractor" NHB 5300. XXX (draft copy May 1969) to incorporate the requirements for hardware and software associated with the ground data handling system and other site requirements. A comparison of NHB 5300. XXX and NPC 250-1 is included in Appendix I.

1A101 Approach

The reliability program plan was prepared based on the following philosophy of management activities to ensure that reliability is a prime consideration throughout the life of the project:

- Establish firm reliability policies and procedures for each area and aspect of hardware and software design, development, test, manufacturing, quality control, purchasing, material, safety, processes, calibration, and packaging.
- Define suitable organizations to implement these policies and procedures.
- Provide continuous monitoring of the reliability program.

With a reliability program of active participation in all phases of the project, a solid basis for design evaluation, reporting, improving, and documenting the equipment and software reliability is assured.

In this document no concentrated effort is made to illustrate a one-to-one correspondence between proven techniques for hardware reliability assurance and methods which serve similar interests for the software counter-part. The areas where software interests are most clearly recognized (design review, recognition of built-in failure structures and corrective action, and test planning) is indicated and elaboration of the specifics of the provisions as applied to software requirements will be provided as required.

1A102 Relation to Other Contract Requirements

The reliability program plan delineates those specific tasks to be performed be reliability personnel. Where the tasks described are common to two or more participants including reliability as one of the participants, the amount of overlap and responsibilities are described.

In case of conflict between this reliability program plan and the ERTS work statement of the contract, the latter will have precedence.

1A103 Action and Prerogatives of the Government

Independent assessment contractors assigned to ERTS by NASA/GSFC will be given access to all needed ERTS performance assurance information generated by TRW Systems Group and subcontractors as specified or approved by NASA/GSFC. This will include but not be limited to:

1) All performance assurance plans and revisions

2) Notification, data packages, and minutes of design reviews

3) Participation in design review and failure review board activities

4) Parts and materials lists and revisions

5) Reliability evaluation program review reports

6) Specifications

7) Reliability predictions, math models, failure mode effect, and criticality analyses and apportionments

8) Reliability assessment reports

9) Failure reports and failure analysis of each reportable failure

10) Lists of suppliers and subcontractors.

1A104 Reliability Documentation

The items of reliability documentation to be delivered to NASA/GSFC are set forth in Table 1.

Table 1. Reliability Documentation

Documentation	Delivery Schedule	NASA/GSFC Approval/ Review Information
Reliability Program Plan	60 days after contract award	Approval
Revised Reliability Program Plan	30 days after NASA requested revisions are received at TRW	Approval
Quarterly Reliability Assessment Reports	Quarterly	Review
Design Review Notifications (TRW/ Subcontractor)	15 working days prior to each review	Information
Design Review Packages (TRW/ Subcontractor)	15 working days prior to each review	Review
Design Review Minutes (TRW/ Subcontractor)	5 working days prior to each review	Review
Failure Report Notification		
• Spacecraft failures after integration	TWX within 48 hours of failure	Information
• Prior to spacecraft integration	Airmail arrive at GSFC within 5 working days of failure	Information
Failure Report Analyses	Airmail arrive at GSFC 5 working days after analysis is completed	Information
Failure Review Board Notification	Airmail arrive at GSFC 5 working days prior to meeting	Information
Failure Review Board Minutes	Airmail arrive at GSFC 10 working days after each Failure Review Board Meeting	Information
Failure Report Summaries	Monthly	Information
Reliability Evaluation Plan	As required by contract work statement	Approval
Reliability Evaluation Program Review Reports	Major milestones	Approval
Parts and Materials Qualification Status Lists	30 days prior to CDR	Approval
Parts, Materials, and Processes Applications Review	30 days prior to CDR	Review
Design Specifications	With CDR data package	Review
Parts and Materials Specifications	30 days prior to CDR	Review
Parts and Materials Qualification Test Specifications	30 days prior to CDR	Review
Test Specifications and Procedures	30 days prior to start acceptance tests	Review
List of Suppliers and Subcontractors Selected After Approval of Reliability Program Plan	30 days after plan approval	Review
Reliability Block Diagrams (as updated)	With design review data packages	Information
Reliability Prediction Models (as updated)	With design review data packages	Information
Failure Mode, Effect, and Criticality Analysis	With design review data packages	Information
Maintainability and Elimination of Human Error Reports	With design review data packages	Information
Parts and Materials Program Progress Reports	As generated	Information
Approved Parts and Materials Lists	30 days prior to CDR	Information
Reliability Assessment Models	With design review data packages	Information
Test Reports	30 days after completion of tests	Information

1A105 Glossary of Terms

The "Glossary of Terms" defined in Appendix A of NPC 250-1 applies.

1A106 Related Documents

TRW Systems Group documents which relate to the Reliability program plan are presented below:

- ERTS - Maintainability Program Plan
- ERTS - Quality Program Plan
- ERTS - Program Plan for Soldering of Electrical Connections
- ERTS - Failure Reporting Plan
- ERTS - Test Monitoring and Control Plan
- ERTS - Configuration Management Plan
- TRW Systems Group - Reliability Manual (RM)

CHAPTER 2: RELIABILITY PROGRAM MANAGEMENT

1A200 Organization

The reliability organization for the ERTS project follows the general TRW Systems Group requirements as defined in the TRW Systems reliability manual. This organization consists of three basic elements:

- Project office having management responsibility
- Functional organizations responsible for supporting each project
- Company staff activities developing general policies and performing auditing functions

Figure 1 illustrates the relationship between the TRW ERTS project reliability with the divisional and corporate reliability support.

1A200.1 ERTS Project Office

Under the ERTS project manager, the primary responsibility for the supervision of reliability activities and management of the reliability program for both spacecraft and GDHS rests with the manager of performance assurance. The manager of performance assurance is supported directly by the reliability departments or staff of the Electronic Systems Division (ESD), Space Vehicles Division (SVD), Science and Technology Division (STD), and Software and Information System Division (S&ISD), and reviewed and audited by the TRW Systems Product Assurance Directorate. In each major area, a responsible engineer is assigned to the ERTS project to ensure adequate support and control functions in these areas.

1A200.2 Responsibilities

1A200.2.1 ERTS Project Office

The manager of performance assurance is responsible for directing the reliability program in a manner which will ensure that the product meets the reliability requirements as defined in NASA document S-701-P-3 and the work statement. His responsibilities include:

- Assigning specific work elements to the divisional reliability departments or other organizations in accordance with functional responsibilities for the equipment being developed

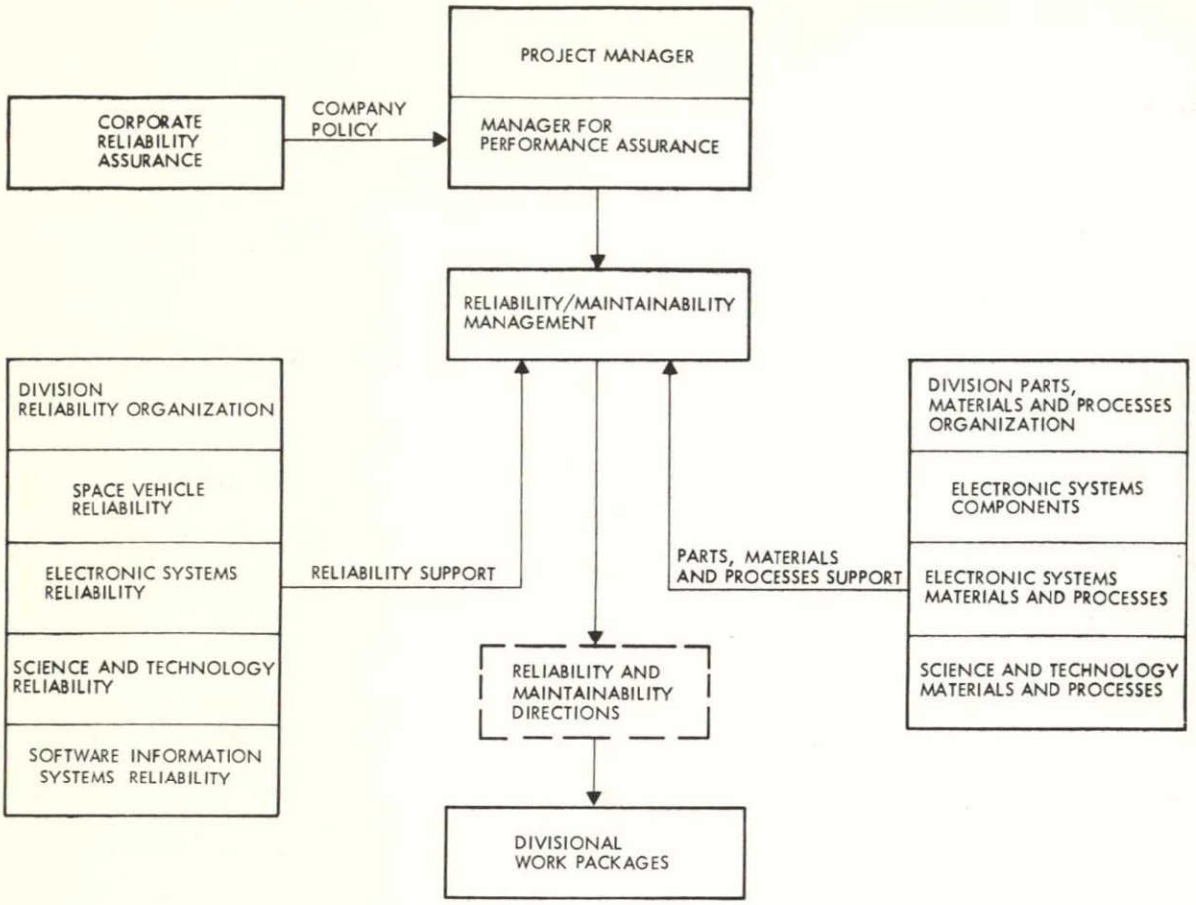

Figure I

PROJECT PERFORMANCE ASSURANCE
SUPPORT INTERFACES

- Controlling budgets and task allocations
- Reviewing progress against milestones and budgets
- Monitoring the performance of reliability and maintainability tasks and initiating corrective action with the cognizant level of management in the functional divisions, if required.
- Representing TRW Systems Group, with appropriate support from other responsible organizations, in dealing with all matters relating to reliability and maintainability on the ERTS project
- Reviewing and approving all official communications to customer affecting reliability and maintainability

- Participating in negotiations with the customer on contract committments, changes, and cost estimates pertaining to reliability and maintainability
- Developing the reliability and maintainability prediction models for the overall ERTS system
- Responsibility for sponsoring and chairmanship of design reviews involving the screening of design features against ERTS project requirements
- Reviewing final selection and control of parts, materials, processes, and sources of supply
- Reviewing and approving subcontractor reliability and maintainability program plans
- Development and approval of environmental design and test specifications
- Coordinating, reviewing, and approving all subsystem and assembly specifications

1A200.2.2 Design Engineer

Design departments with appropriate support from the division reliability staffs, are responsible for designing equipment to achieve the established reliability requirements. As applicable, a numerical reliability apportionment for the equipment is developed. This requirement is included in the design specification. The responsible engineer is responsible for:

- Furnishing the required reliability analyses (e.g., failure mode, criticality, and worst case analysis)
- Providing maintenance and human factors analyses if required
- Presenting the above information as part of the total design review package.

1A200.2.3 Fabrication

The organizations doing fabrication are responsible for:

- Ensuring that the designed reliability of the product is not degraded by the manufacturing process

- Handling failed hardware in accordance with established procedures
- Participating in the review of final design drawings prior to release to ensure compatibility with manufacturing capability.

1A200.2.4 Software Testing

The organizations doing software testing are responsible for:

- Ensuring that proper testing is conducted on the software
- Documenting problems on the prescribed level
- Participating in the review of final software prior to test.

1A200.2.5 Divisional Reliability Departments

The project performance assurance manager assigns the following functions to the divisional reliability departments:

1) Subcontractor control—The divisional reliability departments provide reliability liaison with all major subcontractors. In addition, they participate in the formulation of contract requirements and general surveillance of subcontractor reliability performance in design and fabrication. They are also included in survey teams engaged in the evaluation of suitable suppliers.

2) Review of design specifications—Environmental design and test specifications are reviewed by the divisional reliability departments. The specifications are reviewed against project requirements to ensure adequate environmental requirements and reliability considerations.

3) Estimates and theoretical studies — Reliability estimates are provided by the divisional reliability to determine the probability of each subsystem meeting mission requirements. Periodically, new reliability estimates are performed as a basis for evaluating the ability of the equipment to meet system reliability requirements, to evaluate design changes, and to isolate reliability problem areas. Other theoretical studies relative to reliability estimation and statistical methods are conducted as required. An approach for software reliability assessment is presented in Appendix D.

4) Failure mode analyses — The divisional reliability departments assist the unit engineer in performing the failure mode, effect, and criticality analyses down to the component (assembly) level. These analyses determine for each possible failure mode the effect on mission performance.

Review of the analyses is conducted by the divisional reliability staffs as part of the design review program.

5) Maintainability and human factors analysis— The divisional reliability departments support the responsible engineer in performing the maintainability analysis and human factors analysis required as part of the second and third design reviews. They are also responsible for furnishing required reliability and related data to be used in this task.

6) Design review program — The divisional reliability departments are responsible for documentation of committee proceedings, scheduling, action follow-up, and reviewing the design review presentation. In addition, they assist the design review chairman, a member of the ERTS project office, in conducting the review.

7) Failure analysis and corrective action — Failure analysis and corrective action follow-up are conducted by the divisional reliability departments. These include analysis, correction, and data feedback on all failures and malfunction which occur throughout the fabrication, test, and operation of the equipment. Laboratory analysis of the failure is normally performed by the Components and Materials Departments of the Electronics System Division or the Material Sciences Department of the Science and Technology Division under the direction of the appropriate divisional reliability departments. Detailed analysis of component and subsystem failures is jointly conducted by the responsible unit engineer/project engineer, and the responsible reliability engineer.

Formal activity for software development is not initiated in the code production and routine debug phase. Detailed analysis of computer program failures is jointly conducted by the responsible unit engineer/project engineer, an appropriate representative of the Information Processing Operations of the Software and Information Systems Division, and the responsible reliability engineer as required.

8) The divisional reliability departments are responsible for auditing the Parts, Material, and Processes Program specifications and the suppliers from the reliability viewpoint. The departments also establish the failure rate estimates for the parts being specified in addition to maintaining failure rate histories, disseminating data to IDEP, and responding to GSFC "Alerter" bulletins.

9) Reliability test program and evaluation – The divisional reliability departments participate in the integrated reliability test program to maximize the attainment of reliability data from developmental, acceptance, qualification, and life tests. The reliability departments are also responsible for assisting the manager of performance assurance in monitoring the test programs in the preparation of environmental test specifications. Based on this test program, the reliability departments prepare reliability assessments, updated as required.

1A200.2.6 Specialty Organizations

The following specialty organization support the performance of reliability tasks. These specialty organizations are available to the design activities for consultation and also act as a control function under the direction of the ERTS project office.

a) Components, Materials, and Processes Departments – Under the cognizance of the ERTS project office the Components, Materials, and Processes Departments are responsible for assisting the Design Department in the selection and application of all parts and materials used in electronic subsystems. These departments are responsible for:

- Assisting in the parts, materials, and processes program, including standardization, development, specifications, qualification testing, and application review of parts and materials for all electronic items to be used in the system
- Advising the design groups on the best parts and materials for their application
- Conducting a standardization effort to reduce the variety, styles, and generic part types to the minimum practical number
- Preparing company specifications to meet mission performance for those areas where adequate specifications are not available
- Conducting suitable qualification tests to determine adequacy of the selected parts and materials in meeting system requirements where adequate qualification data are not available.
- IDEP inputs and GSFC "Alerter" investigations
- Preparing and maintaining preferred parts and materials lists for project office approval

- Conducting detailed application reviews to determine that parts and materials are being applied properly for the environment and stress to which they are subjected

b) Material Science Department – The Chemistry and Materials Laboratories of the Science and Technology Division are responsible for assisting the design departments in the selection and application of all materials used for mechanical, propulsion, or structural subsystems. The responsibilities of the laboratories are basically the same as those listed in (a). In addition, the department performs research and investigations into various materials for aerospace applications. These studies include the effects of vacuum, radiation, and high levels of shock and vibration. The results of these studies are used to improve the reliability of spacecraft packaging and structures.

c) Quality Assurance (QA) – Quality assurance ensures that the inherent designed reliability is not degraded during the fabrication, integration, or testing cycles within the company's manufacturing operations and that specified reliability requirements such as parts screening are accomplished. It is also responsible for ensuring the maintenance of the required quality level at the vendor's plants. This is accomplished by means of surveys, evaluations, and surveillance. In addition, quality assurance is responsible for verifying that failure reports are prepared and that failed hardware is disposed of properly.

The quality assurance function is fulfilled within Software and Information Systems Division – Product Assurance in a manner consistent with the organizational structure, established responsibilities of the S&ISD line organization, and optimization of use of available automated techniques. This function is accomplished primarily by means of continued surveys of the state of the art in software quality assurance and design and development of automated tools (Product Assurance Checkout and Evaluation System) to assist in the quality assurance task throughout the software development cycle, thus enhancing the reliability of the completed product.

1A200.2.7 Reliability Assurance (RA)

The prime responsibility of the corporate reliability assurance is to develop overall policies and procedures for the conduct of reliability programs. In addition, this organization is responsible for:

- Auditing programs to ensure compliance with the reliability requirements of the customer

- Performing periodic detailed audits to investigate potential reliability problem areas
- Continually reviewing reliability practices, policies, and procedures to provide for the development of new techniques as necessary
- Implementing suitable training and indoctrination programs to ensure that design, manufacturing, and other personnel are aware of the latest reliability methods
- Establishing suitable standard design practices and ensuring their utilization to the maximum extent possible
- Reviewing reliability sections of major proposals and reliability program plans
- Establishing a company-wide failure correction system to provide failure analysis, corrective action, and reporting continuity from program to program for maximum benefit to all programs.

1A201 Reliability Program Plan

The reliability program plan described herein is the master control document for the ERTS Phase D Contract. The plan has been developed in conformance with NPC 250-1. "The Reliability Program Provisions for Space Contractors" and as amended by the contract work statement. This plan will be updated periodically as specified in the contract.

1A202 Reliability Program Control

1A202.1 General

The Manager of Performance Assurance has direct responsibility for all ERTS reliability activities and for their being conducted through to successful completion.

Each major task within NPC 250-1 will be assigned a cost code, a group (identified by names to accomplish the task), and a scheduled date for task completion. The manager of performance assurance reviews, on a monthly basis, the changes accumulated by task number, the participating organization identifying code, and the names of the persons changing. A cumulative record of the task effort being expended versus the projected task output is maintained to assure completion within the budget and on schedule. Variances indicating potential problem areas are resolved with the responsible organizations.

1A202.2 Reliability Program Evaluations

TRW Systems Group and the cognizant NASA installation will jointly conduct reviews of the reliability program, including major subcontractors, to assess its progress and effectiveness. Reviews based on particular problem areas or required by major redesign can be called by TRW or NASA/GSFC as required. The reviews will be documented by TRW Systems Group. Proposed revisions to the reliability program plan, within the scope of the contract, will be submitted to NASA/GSFC for approval within 30 days following the review.

1A203 Reliability Progress Reporting

1A203.1 General

Written reliability progress reports will be furnished to NASA/GSFC in accordance with the requirements of the work statement. Each report will also include information from each major subcontractor. In conjunction with the written reliability progress report, joint contractor/NASA management meetings will be held to discuss pertinent items requiring clarification or additional information.

1A203.2 Written Progress Reports

The periodic written reliability progress reports will include separate sections for significant technical accomplishments and milestones completed, summary descriptions of each active major task, problem areas and status of proposed corrective action, revisions to work scheduled and work scheduled for next reporting period, decisions and actions affecting reliability tasks and their effect on system reliability, and an overall discussion of reliability program status.

1A203.3 Reliability Program Control Reports

The manager of performance assurance will submit periodic reliability control reports to the extent specified in the work statement.

1A204 Reliability Training

Reliability orientation and indoctrination conducted in both written and oral form is a continuing program at TRW Systems Group. Training courses for the various activities involved are given by the TRW Systems corporate product assurance staff using lectures, slide presentations,

as well as manuals, charts, and other training aids. Typical courses to be presented to ERTS personnel include:

- Soldering to NASA quality requirements
- Soldering of electrical connectors
- Module welding
- Radiographic inspiration
- Dye penetrant inspection
- Ultrasonic inspection
- Use of software test tools.

1A205 Subcontractor and Supplier Control

1A205.1 General

Assurance that suppliers and subcontractors of deliverable equipment will be governed by ERTS quality and reliability requirements is provided by a supplier quality and reliability control program. Control of contractor procured material is defined in the ERTS quality program plan.

1A205.2 Reliability Program Requirements for Major Subcontractors

Applicable provisions of NPC 250-1 are imposed on major subcontractors by the subcontractor reliability requirements document, PAR-700-54, presented in Appendix C.

1A205.3 Resident Representatives

A TRW Systems Group resident technical representative is assigned as appropriate to monitor and assist in the direction of reliability programs at major subcontractor facilities when critical assemblies are involved.

1A205.4 Reliability Controls for Subcontractors and Suppliers not Classified as Major

All hardware suppliers and process houses not defined as major are subject to the applicable reliability and quality assurance provisions of NPC 200-3. In those cases where the requirements of NPC 200-3 may be deleted, the reliability and quality levels are imposed by the

various specifications to which the parts are procured. In conjunction with the parts, materials, and processes program established in paragraph 1A308 of this plan, a supplier quality and reliability control program includes a supplier survey to check the supplier's capability prior to award of a contract. The survey is performed by a team of specialists, each of whom rates the supplier in his particular field. The supplier's reliability capability is evaluated by a reliability staff specialist. Consideration is given to previous reliability history, use of effective reliability methods and procedures, and use of experienced reliability engineers.

After award of a contract to a supplier, continuous surveillance of his activities is maintained. During the engineering phase, this is done by design reviews in the supplier's facility. During the fabrication/test phase, surveillance is performed by TRW Systems Group quality assurance personnel.

For electronic piece-parts, supplier and parts selection includes concurrence by the TRW Systems Group parts specialists. Concurrence applies to specific parts and to specific vendors for which sufficient reliability data history are available to provide confidence. Surveillance during fabrication is provided by TRW Systems Group source inspection of the supplier's facility.

1A206 Control of Government Furnished Property

Assemblies that are government furnished property (GFP) will be reviewed by reliability personnel to determine compatibility with ERTS requirements. Where differences are noted, NASA/GSFC will be notified for appropriate action.

Reliability assessments of GFP will be conducted to the same level and schedule as that performed for TRW Systems Group designed equipment.

CHAPTER 3: RELIABILITY ENGINEERING

1A300 General

This section describes the basic elements of the reliability engineering program

1A301 Design Specifications

1A301.1 Generation and Control

The office of the manager of performance assurance is responsible for the generation and maintenance of ERTS design and environmental specifications. These specifications are maintained at the observatory, system, subsystem, and component assembly level, and cover all items of ERTS flight and ground hardware.

Reliability requirements are delineated in the individual subsystem, assembly, and subassembly specifications. These requirements include specifying the numerical reliability probability figure which applies under stated conditions for a specified period; it is obtained from the appropriate budget. The initial subsystem budget is established by the manager of performance assurance within the ERTS project office. A preliminary reliability assessment of the system to determine the quantitative reliability relationships of the various subsystems was performed and is included in the ERTS phase D proposal. Based on these estimates, an apportionment was made to establish the system reliability budget, consistent with the established design goal for the system. In a similar manner, the budgets for the various assemblies and subassemblies will be established by the responsible subsystem and unit engineers, respectively. The establishment of these budgets is supported and checked by the appropriate division reliability staff.

The reliability requirements indicated in this section as being delineated in the individual subsystem, assembly, and subassembly specifications, and calling for assignment of numerical reliability probability figures do not apply to software (i.e., computer program detailed design specifications).

1A301.2 Updating and Review

Under the cognizance of the manager of performance assurance revisions or deviations to the specifications are prepared by the office of the responsible subprogram manager within his design department or laboratory. All specifications issues, revisions, and deviations bear the signature approval of such subprogram manager and of the manager of performance assurance. All revisions or deviations are subject to NASA review. The specification tree of the ERTS project is contained in the ERTS configuration management plan.

1A302 Reliability Prediction and Estimation

The overall reliability prediction for the ERTS observatory system is contained in ERTS technical proposal, Part II, Volume 3. For the prediction, three equipment status states were required to complete the analysis.

- Flight tested equipment not requiring redesign
- Flight tested equipment requiring redesign or modification
- New design equipment

Included in the predictions are functional block diagrams down to the component level or major function level as appropriate to define the operation of the equipment.

Failure rates used in the prediction were selected in the following order of precedence:

- TRW System Group approved failure rates
- NASA supplied failure rates
- Vendor supplied failure rates
- Other sources

The reliability predictions for electrical equipment were performed using the parts population method. Design furnished part stresses (electrical and thermal) were used in the prediction where available. For parts where stress data were not available, a nominal 30^{o} ambient temperature and 25 percent electrical rating were used. Mechanical and structural equipment were assessed to determine their inherent reliability.

The classical techniques for hardware reliability prediction and estimation are not directly applicable to the software development effort. Basic assumptions about characteristics of software (including that it does not wear out and that reliability evaluation is a function of effective test efforts as opposed to part failure rates and time used) set the software provisions apart from those outlined here for other equipment.

1A303 Failure Mode Effect and Criticality Analyses

Failure mode effect and criticality analyses will be performed to the component assembly level or major functional level as appropriate to the operation of the equipment.

In performing the failure mode, effect and criticality analyses each potential failure mode will be evaluated (1) as to the probability of occurrence, (2) the effect on the probability of mission success, and (3) alternate means of negating or minimizing the failure.

During the phase D contract, the failure mode effect and criticality analyses will be continued through the final design reviews to ensure elimination of all single failure points from the design.

1A304 Maintainability of the System and Elimination of Human Induced Failure

During the design of the phase D contract, the reliability predictions, failure mode effects, and criticality analyses will be used as a basis in the design to develop and define the maintenance concept and checkout equipment and procedure for both the observatory and the GDHS or defined in the maintainability program plans. Analyses will be conducted to assure that each failure mode can be detected and localized to a repairable item and that the equipment provides safe and ready access for such repair. In addition, a review of the human factors and man-machine interfaces will be made to assure that the equipment can be operated in a safe and reliable manner and that sources of human-induced failures are eliminated. Particular emphasis will be placed in reducing human induced failures in all areas of hardware and software for the GDHS, ground support, mission operations, and launch support.

A continuing TRW product assurance training program available for ERTS personnel includes instructions in the improvement of competence

in detailed technical application, the improvement of motivation, training of supervisors, inspectors and assembliers, the supplying of current information on product improvement methods to product assurance manager and supervisors, the improvement of supervisory skills, interpersonnel skills, and provide newly hired members of the technical staff with briefing in the above areas. The goals of the product assurance training program are to:

- Improve understanding of total quality effort
- Identify the individual's role
- Improve skills

Special concentration will be applied in the early stages of software design and development to eliminate all possible built-in failure structures, incorporating techniques which ease the continuing tasks of isolating and correcting sources of software problems (errors) and validating the correction. Key features of this approach will emphasize modularity and functional independence of programmed modules and use of available test tools (PACE) in the validation process.

1A305 Design Review Program

1A305.1 General

The design review function provides a progressive evaluation of design requirements and concepts throughout the design, fabrication, development, and operational program. It assures that all significant factors affecting function, reliability, and potential reliability degradations have been properly considered. It also assures that all possible use is made of past experience accumulated in malfunction analyses, data retention files, check lists, procedures, specifications, failure mode effect, critical analyses, and other similar analyses. In this manner the highest possible reliability for flight hardware and for software and highest availability for GDHS hardware is designed into the equipment and software.

The basis for the informal and formal design review activities required in the software development cycle is to ensure design objectives which encompass utilization of a modular design approach, re-use where at all possible of existing proven software, and incorporation of increased testability through designed-in module independence.

1A305.2 Design Reviews by the Contractor

During phase D, formal design reviews will be held by TRW Systems Group on all new designs and all current designed equipment for ERTS that require redesign. The procedure for design reviews is contained in Appendix 2. The number of design reviews to be conducted will depend upon the state of the design at the beginning of phase D.

Normally there are four check points where it is convenient and expeditious to conduct design reviews:

- As early as possible after basic concepts have been defined (conceptual)
- For electrical and electronic equipment, after circuit design and breadboard testing are completed. For mechanical, structural, and propulsion equipment, after initial design and engineering model testing has been completed (development)
- After all drawings are compiled (final)
- Design review for subcontractor and vendor items

Design Review Number 1 (Conceptual)

The preliminary design review number one was performed during the study phase. The review will be completed as shown on the master project chart for phase D. These two reviews (study phase and phase D) will cover the entire system on a subsystem-by-subsystem basis. The word subsystem is defined as being major hardware groups of relatable operational nature. The purpose of the conceptual review is to determine that the contractual and system requirements are clearly defined, that the selected design approach is properly justified, that the approach satisfies the requirements, and that any problem areas are identified and tasks are assigned to provide immediate solutions.

This review is held as soon as preliminary design studies have established the preferred basic system concept. The preliminary design

review number one established during the study phase for the spacecraft and GDHS will be finalized in the first design review of the phase D contract. Major factors to be considered in the design review number one are:

- Review of contractual requirements
- Preliminary subsystem specifications
- Preliminary unit design data sheets
- Subsystem block diagram
- Unit or assembly block diagram (component)
- Functional description
- Interface compliance data (requirements of contract and other interfacing equipment versus design provisions of form, fit, and function)
- Performance analysis considering electrical, thermal, mechanical, and RFI requirements
- Packaging concept (top assemblies or exploded views to sub-assembly levels and estimated weights)
- Preliminary parts lists
- Developmental test plans
- Developmental and factory test equipment requirements

Design Review Number 2 (Research and Development)

This is a subsystem review by equipment unit (component level). The review verifies the adequacy of finalized designs implemented based on approvals from phase D design review number one and any modification thereto. It establishes the requirements for advance procurements when necessary and initial reliability assessments and predictions as well as parts, materials requirements, and identifies problem areas and makes task assignments for their timely solutions. This review will be held as early as practical in the development phase after initial breadboard testing. No detailed drawings are prepared until review approval is obtained unless specified by the project manager.

Major factors to be considered in design review number 2 are as follows:

- Review of contractual requirements
- Subsystem specifications
- Unit design data sheets
- Subsystem block diagrams
- Component block diagrams and schematics
- Functional description
- Interface compliance data
- Performance analysis considering electrical, thermal, mechanical, and RFI requirements
- Breadboard and/or engineering model test data
- Reliability assessments, availability analyses, failure mode, effect and criticality analyses
- Parts lists
- Materials and processes lists
- Design selection analyses
- Preliminary weight and center of gravity data
- Equipment and procurement specifications
- Preliminary packaging drawings
- Preliminary test specifications and/or calibration procedures
- Developmental and factory test equipment design data

Design Review Number 3

This is a preproduction release review of each unit conducted after engineering model evaluation tests. This review verifies that:

- All design limiting action items from prior reviews have been satisfactorily accomplished.
- The design as finalized meets the currently existent contractual and system requirements of form, fit, function (performance, environmental survival, interface, weight, reliability, and maintainability.
- Good practices of design have been utilized to provide for ease of manufacture, repair, adjustment, and inspection

- The design and its related detailed drawings and specifications are complete and ready for release to manufacturing.

No release to production may be made until all design-limiting actions are completed and review approval is given, except where specifically waived by the project manager.

Some of the primary factors to be considered in design review number 3 are:

- Review of any customer requirement changes
- Equipment specifications (final)
- Final top assembly drawings and schematics (to module for drawer level) prepared for release approval
- Maintainability of flight and ground support equipment
- Maintainability of GDHS equipment
- Performance analysis (for significantly revised or redesigned equipment or subassemblies)
- Weight and center of gravity data (final)
- Failure histories (of test articles)
- Test specifications and calibration procedures (final)

The critical review number 3 for software provides NASA with an opportunity to review the preliminary version of the Milestone D software design. The Milestone D components are reviewed sequentially in a series of meetings to ensure compliance with Milestone A design requirements, Milestone B implementation concepts, and Milestone C interface specification.

Design Reviews for Subcontracted Items

For all major items of equipment designed and supplied by subcontractors to TRW Systems Group specifications, (major subcontractors are defined as those suppliers that are required to submit and work to TRW Systems Group approved reliability program plans). Design reviews are held in accordance with the program elements outlined above with TRW Systems Group personnel in attendance. The specific design review requirements for each major subcontractor are detailed in the purchase order.

1A305.3 Sequence of Events

The following sequence of events will apply to each design review held at TRW Systems Group and major subcontractors during the phase D contract:

- Design review master schedule issued monthly or as required by the project schedules.
- Division design review schedule issued monthly or as required by the project schedule.
- Meeting notices issued not less than 15 working days in advance of each review with formal notification to the procuring NASA installation or its designated representative.
- Design data packages issued 15 working days prior to each review with formal transmittal of copy to the procuring NASA installation or its designated representative.
- Design review minutes issued within 5 working days after each review meeting and with formal submittal of copy to the procuring NASA installation or its designated representative.
- Design review report issued within 30 calendar days after each review with formal submittal of copy to the procuring NASA installation or its designated representative.

1A305.4 Engineering Design Changes

Design changes on individual units after the conclusion of qualification tests or whenever, after the normal release to manufacturing has occurred, significant quality, performance, or reliability deficiencies are disclosed, or whenever major redesigns are required will be handled through the formal TRW Systems Group change evaluation control board (CECB) described in Section 5 of the ERTS configuration management plan. Any subsequent design reviews required by the CECB will be structured following the general guidelines of design review number 3 described above.

1A306 Problem/Failure Reporting and Correction

The detailed problem/failure reporting and correction for ERTS phase D is described in a separate document. This is in conformance with paragraph 7.11.6.1(f) of the NASA/GSFC design specification S-701-P-3 where a separate failure reporting plan is acceptable to NASA/GSFC.

Procedures have been incorporated to extend proven techniques of malfunction reporting and correction for hardware systems to encompass the later stages of the development, test, and operational phases of software preparation. Modification of those techniques provides for processing of software problem reports, assurance of proper and timely corrective action (coordinated with the ERTS CECB as required by the divisional reliability staff representative) and feedback and documentation for use in subsequent analyses and maintenance of over-all system failure data.

1A307 Standardization of Design Practices

The standardization of design practices and the ensuring of a formalized quick-fix procedure at TRW Systems Group are described in the following company standard practices:

- CSP 9.22 Engineering Data
- CSP 9.16 Management of TRW Controlled Engineering Manuals
- CSP 9.15 Engineering Checking
- CSP 9.14 Issuance and Control of Expedited Engineering Orders
- TRW Systems Programming Handbook
- S&ISD Software Development Manual

These documents define standard practices and associated organizational responsibilities relating to the preparation, coordination, approval, and maintenance of engineering data.

It is the direct responsibility of the manager of performance assurance to assure compliance with the standard practices listed above throughout the ERTS project and further to assure that the controls are placed on subcontractors when applicable.

TRW Systems Group maintains a formal manual system to ensure common design, drafting, manufacturing, quality, quality inspection, reliability, specification, configuration, maintainability and other related disciplines. These manuals are used to the fullest extent possible, within the contractual requirements, on each project.

The ERTS reliability organization will review the contractual reliability requirements to determine what changes if any are required

in the TRW Systems Group manuals to comply with the contractual requirements. This review will also include major subcontractor manuals.

1A308 Parts and Materials Program

1A308.1 Introduction

Surveillance of parts, materials, and processes functions will constitute one of the major performance assurance activities of the project. To fulfill the stringent project reliability requirements, constant emphasis must be exerted of the selection, evaluation, testing, and handling of all critical parts and materials. Careful control must be used in the selection, application, and documentation of materials and processes.

The selection, test, evaluation, and specification preparation of parts and selection and specification preparation of needed material and process specifications will be performed by specialists from the Components, Materials Engineering, and the Materials and Processes Departments assigned to the project.

Selection, test, evaluation, specification preparation, handling of parts materials and processes, the preparation of material processes, and parts specifications are prime responsibilities of the manager of performance assurance. This places in the project office a central control on the parts, materials and processes. The following parts and materials program delineates the tasks performed on the project for the selection, reduction in number of types, specifications, and application review of parts, materials, and processes for all items used on the project.

1A308.2 Parts Program

The manager, performance assurance is responsible for the parts program, for electromechanical and mechanical parts to support functional and packaging design. These responsibilities include selection of parts, establishment of preferred parts lists, evaluation of vendors and parts, preparation of definitive procurement specifications, analysis of parts reliability information, participation in supplier evaluation, supplying of parts application information for equipment reliability, and participation in design analysis reviews. A parts evaluation laboratory will furnish test data on the performance and characteristics of electronic and

electromechanical parts. Because of the specialized technology involved in semiconductor evaluation, special attention will be given to this field.

Parts selection for the project will include representation from the various company divisional reliability and quality assurance staffs, electrical and mechanical design organizations, Components Department, the Material Engineering Department, and Procurement. Typically, the proposals for including parts on the list of preferred parts are made by the Components Department and the parts proposed are selected on the basis of functional need, reliability, mechanical configuration, availability, and cost considerations. GSFC PPL-10 will be used as a basis for the selection procurement and stocking of all parts.

Any deviation to the lists of preferred parts for the spacecraft and for the GDHS requires the approval of the manager of performance assurance. Deviations may reduce cost or delivery time if no reduction in reliability or quality results which might degrade the total system reliability. Instances will also occur where functional needs cannot be achieved with the list of preferred parts. Newly identified parts will be procured with existing specifications wherever possible. These specifications can be TRW Systems Group devices that are not on the list of preferred parts, MIL Specifications that are adequate, or individual vendor identified parts that are available. Regardless of the route taken, all necessary control steps will be exercised to guarantee that the part is completely defined with appropriate quality control, reliability, and packaging provisions to ensure homogeneous lots.

If no adequate specification exists for a part that is selected, a specification will be written including all factors that are needed to achieve high reliability with proper quality control. The specification will be provided to prospective vendors for their concurrence prior to its release. In this way, assurance is provided that the specification is realistic in its method of achieving high reliability.

Because of the tight control that will be exerted to minimize new specifications and because a comprehensive list already exists, few items will be in the category of newly identified parts. Thus a concentrated effort will be exerted to do a complete job of defining the part in the shortest possible time.

Eligibility of vendors to furnish material to TRW Systems Group is established as required by company standard practice 6.16,

"Preprocurement Supplier Surveys," and maintained current as prescribed in company standard practice 6.19, "Supplier Surveillance and Performance Evaluation." Emphasis is placed on the product having a record of proven reliability. Usually, qualification testing is conducted by the vendor, commercial facility (with certified data) or by TRW Systems Group. Successful completion of qualification testing and conformance with the requirements results in an entry in the TRW Systems Group "Approved Vendor List." Procurement is limited to vendors so listed. Receiving inspection is conducted in accordance with quality control requirements set forth in the part specification and amplified by a quality assurance incoming inspection procedure. Typically the parts specifications require submittal of certified acceptance test (both 100 percent and sampling) data for review and feedback through the mechanisms of CSP 6.19 cited above.

Where feasible each part will be stamped with a date code or other suitable designation to trace the lot in case of failure after the part leaves the vendor.

To prevent part degradation by handling and/or storage, special handling and storage procedures will be formulated. These will include:

- Special storage to reduce possible damage
- Controlled environments for assembly
- Controlled environments or plastic containers for storage
- Complete part surveillance throughout the program

The activities of parts specialists from parts, materials, and processes engineering will also extend into subcontracts of major equipments in conformance with TRW Systems Group subcontractor reliability requirements document PAR-700-54 for flight equipment as shown in Appendix C and PAR-700-55 for GDHS equipment as shown in Appendix E. Each major subcontractor will be required to implement a program covering selection, reduction in number of types, specification, and application review of parts for all items to be used in the system. A description of

this program will be submitted for TRW Systems Group review. The subcontractor will be required to identify the organization that has the responsibility to act as advisor or control point for design group on the application and selection of parts and to conduct the parts program. A description of the organization and procedures to be employed in this activity will be included in subcontractor's program for TRW Systems Group review. Prior to finalization of the design of each component, each major subcontractor will conduct a thorough applications review to determine the applicability of each part in that design to mission profile requirements, e. g., stress analysis for electronic assemblies. These reviews must be thoroughly documented and will be considered a check list item for formal design reviews.

The preferred parts list will be maintained with definitive specifications and application data defined in a proper manner. This list will include all items which must be incorporated due to their identification by a subcontractor. The physical entry will occur when it is decided by mutual concurrence between TRW Systems Group and the subcontractor that the part must be included.

An electronics, electromechanical parts matrix will be created and maintained for the observatory. This matrix will list all electronic, electromechanical, and mechanical parts. No attempt will be made to indicate quantities used or subassemblies on which these parts will be used. The parts list will be compared with GSFC PPL-10 and deviations will be noted. Parts for the GDHS designed equipment will be selected from the following sources and in the order listed:

- Select from the preferred parts defined in the ERTS GDHS parts standard
- Select from MIL Spec on MIL STD types not identified in the ERTS GDHS parts standard
- Select from high quality commercial suppliers

Traceability of parts to assemblies and subassemblies is maintained by the Consolidated Indentured Parts List (CIPL) and the System Parts Accumulation Index (SPAI). The CIPL is an indentured listing of configured items to the lowest indenture level of assembly. It includes the applicable specifications and test procedures as well as the code identification for purchased parts. The SPAI is an alphanumeric order computer printout of all parts and applicable specifications and procedures in the system. It is obtained from the same data used to produce the CIPL.

Parts specialists will participate in the design reviews as a member of the review board. Concurrence with the design will be made by sign-off of the drawings and specifications when all conflicting items have been resolved. Final resolution will rest with the manager of performance assurance.

Parts and materials failure analysis required for nonconformance on higher levels of assembly are described in the failure reporting plan written in response to paragraph 7.11.6.1(b) of Specification S-701-P-3.

1A308.3 Materials and Processes Program

The manager of performance assurance is responsible for the ERTS materials and processes program. This program includes preparation and updating of the approved materials and processes list, and effecting controls for the use of all materials and processes.

The materials and processes specialists will provide materials and processes guidance to the project through continuous design consultation, research and development of materials, developing process and fabrication technology, and writing process and materials specifications.

The prime source of materials and processes for the project is the TRW Systems Group Materials and Processes Engineering Handbook. New specifications written for materials and processes not covered in the Materials and Processes Engineering Handbook will be controlled by the parts, materials, and processes manager who will have the final authority on any deviation required.

A thorough application review of each material and process required on the project will be made. Each review will consider the conformance of the project requirements to existing TRW Systems Group

approved specifications. When the need for new materials and processes is indicated, it will be the responsibility of the parts, materials, and processes manager to direct the development and implementation of the necessary revisions or new specifications.

Materials and processes specialists will participate in the design reviews as members of the review board. Concurrence with the design will be made by sign-off of the drawings and specifications when all conflicting items have been resolved.

When a material or process specification is released, it will be reviewed by the manufacturing process section. Some specifications are sufficiently definitive so that no additional directions are needed for the manufacturing division. Other specifications cannot be used by non-technical personnel without additional instructions. If the specification needs detailed step-by-step instructions to carry out the process in manufacturing, a fabrication process procedure (FPP) is written by the manufacturing process section with direction from materials and processes specialists. This could be a general document for a particular application. These documents are reviewed by the quality assurance organization for concurrence prior to being released for use.

In a similar fashion, all material or process specifications must be reviewed by the quality assurance organization. This review is to determine if sufficient instruction is provided for inspection personnel. It is always necessary to provide workmanship criteria for satisfactory results from the process and to provide detailed surveillance and inspection instructions to verify these results.

In this way each process specification is well defined as to the engineering requirements that are established, the means of achieving these requirements, and the verification that these requirements have been achieved.

CHAPTER 4: TESTING AND RELIABILITY EVALUATION

1A400 General

For the ERTS project an integrated test program in conjunction with reliability assessments will be performed throughtout the course of the project beginning with developmental tests and extending through orbital operations. The related tasks of environmental testing, test monitoring, failure mode, effects analyses, and reliability assurance analyses are coordinated and approved by the manager for performance assurance, thus permitting the correlation of prediction and test results as well as the monitoring of the effectiveness of corrective action.

All testing conducted where reliability of the product could be affected will be evaluated to correlate the test results with reliability predictions. Where failures occur and corrective action is required, subsequent testing will be evaluated to verify the effectiveness of any proposed changes. Thus, a degree of confidence is established that the equipment meets the requirements of the mission. Reliability data will be derived from the following primary sources:

- Tests of parts and materials
- Environmental and functional tests of developmental hardware
- Qualification test data from environmental and functional tests of parts, components, subsystems, and systems
- Acceptance test data from environmental and functional tests of components, subsystems, and systems
- Operational data from integration, prelaunch, launch, and orbital operations

An exception to the above is that testing of software at all stages of the project provides an accumulation of test data from which a meaningful evaluation of software reliability can be made. The ultimate objective is not correlation of test results with previously generated reliability predictions, but rather a steadily growing confidence that the accomplished testing guarantees adequate environmental software operation. The basic assumption that software reliability increases as the software is used and

failures are identified and corrected is fundamental in the requirement for test data accumulation and analysis as part of a well planned software testing activity. A key element of the approach to best fulfill this requirement is the extensive use of automated, software quality assurance techniques (PACE) to aid in identification of computer program failure structures, preparation and maintenance of test data, and analysis of test results with measures of test plan effectiveness.

1A401 Reliability Evaluation Plan

The detailed reliability evaluation plan will be submitted in accordance with the phase D work statement.

1A402 Testing

1A402.1 General

The initial task in the environmental test program is the establishment of the general environmental test specifications. Exposure levels for environmental qualification and acceptance tests are detailed in the environmental specifications. These specifications will be reviewed by reliability personnel to verify adequacy to meet the stated objectives and to recommend changes in the tests to increase the reliability data output.

1A402.2 Qualification Testing

Qualification tests will be performed on prototype components assemblies to qualify the design for the intended application. Laboratory environmental qualification tests will simulate conditions that are more severe than the environments for transportation, handling, storage, launch, and flight but do not exceed design safety margins. The qualification test articles are representative of the flight hardware.

Particular emphasis will be placed in searching the design for deficiencies and in keeping accurate test records, failure and rejection reports, and engineering data. Fabrication, design, and quality personnel will be informed of design deficiencies as they are revealed to solicit their recommendations. Interface problems between assemblies of a subsystem will be evaluated.

All parts, devices, and materials for use on new builds for ERTS are qualified by testing or by documented similarity. The detailed parts and materials lists for use on ERTS are furnished as a section in the ERTS phase D proposal in response to paragraph 7.11.4 of NASA/GSFC Specification S-701-P-3.

A significant task which must be performed through the combined efforts of the responsible unit/engineer/project engineer and the responsible reliability engineer is the identification of highly critical elements of the GDHS software. This is followed by a determination of cost effective testing techniques which ensure maximum confidence in the ability of the identified critical components to meet specified requirements. Appropriate measures dependent on the nature of criticality of items identified will be implemented and data supplied as necessary for performance of failure mode, effect, and criticality analyses. Valuable assistance will be provided in accomplishment of this task through use of software quality assurance test tools as appropriate. Specific features which will be helpful in this regard include automated identification of portions of computer programs which are either used a great deal or never exercised by the test plan, and subsequent assistance in generation of supplementary test data as well as intermediate reports which indicate the summary effectiveness of testing thus far accomplished with an identification of potential problem areas.

Component assembly qualification testing will be performed on the prototype model of each unit in the ERTS spacecraft. The requirements of each component will simulate conditions more severe than the component will endure in operation.

1A402.3 Test Specification, Procedures and Reports

The details of the test specifications, procedures, and reports required for ERTS are described in the ERTS configuration management plan.

1A402.4 Life Testing and Reliability Demonstration

No formal life tests or reliability demonstration tests at the component and higher levels of assembly are anticipated for the ERTS

contract. Data evolving from prototype, qualification, acceptance, and flight will be analyzed to measure system reliability.

1A403 Reliability Assessment

TRW Systems Group will update the reliability predictions described in paragraph 1A302 above during major milestones in the phase D program. The revised assessments will factor in the results of applicable tests, additional mathematical analyses, and additional engineering analyses performed subsequent to the initial prediction. The revised assessments will reflect all applicable design changes and refinements subsequent to the previous assessment.

1A404 Reliability Evaluation Program Reviews

At major milestones specified in the work statement joint NASA/ TRW Systems Group reviews will be held to assess the ERTS reliability evaluation program. For each review, the tests results and resulting updated reliability assessments will be critically examined. The results of each review will be documented and submitted to NASA/GSFC for approval.

APPENDIX A

COMPARISON OF NHB 5300 XXX AND NPC 250-1

NHB 5300 XXX May 1969		250-1 July 1963
Reliability Program Management		Program Management
1A200	Organization	2 1
1A201	Reliability Program Plan	2 2
1A201	(2) Separate Site Plan	---
1A202	Reliability Program Control	2 4
1A202	(2) Reliability Program Audits	---
1A203	Reliability Progress Reporting	2 3
1A204	Reliability Training	2 5
1A205	Subcontractor and Supplier Control	2 6
1A206	Control of Government Furnished Property	2 7
Reliability Engineering		Reliability Engineering
1A300	General	3 1
1A301	Design Specifications	3 2
1A302	Reliability Prediction and Estimating	3 3
1A302	(2) Functional Block Diagrams	---
1A303	Failure Mode and Contingency Analyses	3 4
1A304	Maintainability and Elimination of Human Induced Failure	3 5
1A305	Design Review Program	3 6
1A306	Problem Occurrence Reporting, Correction, and Recurrence Prevention	3 7
1A306	(1) (a) (b) (c) (d) (e) (f) (g) (h) Attributes of the Activity	---

NHB 5300 XXX May 1969		250-1 July 1963
Reliability Engineering (continued)		Reliability Engineering
1A306	(2) (a) (b) Information to be submitted	---
1A307	Standardization of Design Practices	3 8
1A308	Parts and Materials Program	3 9
Testing and Reliability Evaluation		Testing and Reliability Evaluati
1A400	General	4 1
1A401	Reliability Evaluation Program	4 2
1A402	Testing	4 3
1A402	(3) (a) (b) (c) (d) Qualification Testing	---
1A402	(4) Test Specification Procedures and Reports	---
1A402	(5) Life Testing and Reliability Demonstration	4 3 4
1A403	Reliability Assessemnt	4 4
1A404	Reliability Evaluation Program Reviews	4 5
Covered in NHB 5300 4(1B) para 1B706		3 10

APPENDIX B
DESIGN REVIEW, GENERAL PROCEDURE

1 PURPOSE

This general procedure provides design review practices and methods applicable to the assurance of designs characteristic of product lines General methods are outlined to assure that design reviews meet the primary objectives of TRW Systems Group as prescribed in standard practices Definitions are given for the essentail administrative and technical phases of design review procedures Standards for minimum technical participation in design reviews are established for development projects characteristic of product lines

2 APPLICABLE DOCUMENTS

All of the following company and Government documents are applicable to the definition and description of design reviews as established in this general procedure Specific methods provided herein are directed toward satisfying the reliability program requirements for design review (given in documents a and b)

a TRW Systems Group, Reliability Manual RMS-5 (Design Review)

b NASA, NPC 250-1, Reliability Program Provisions for Space Systems Contractors

c NASA, NHB 5300 4-1B, Quality Program Provisions for Aeronautical and Space Systems Contractors

3 DEFINITIONS

3 1 DESIGN REVIEW

A procedure for the timely reexamination of the details of a design (disclosed in the form of prescribed engineering data) by experienced technical specialists who have not themselves contributed directly to the documented design decisions Design reviews will achieve this primary purpose as well as secondary purposes of (1) project status reporting and (2) intra-project communications

3 2 DESIGN REVIEW CYCLE

The set of sequential events which provide for (1) an orderly consolidation of engineering data for design disclosure, (2) study of this data by impartial specialists, (3) recording of recommended corrective measures, and (4) the assignment (and follow-up) of action items where warranted The establishment of pertinent design-change recommendations is the principal purpose of assigning action items within a design review meeting

3 3 DESIGN REVIEW MEETING

A formalized technical conference (providing for a chairman, secretary, and meeting minutes) for the purpose of recording design corrective measures recommended by the impartial specialists who have previously studied the disclosed engineering data Design review meetings will minimize the utilization of time for restating information already contained in the disclosed engineering data

3 4 DESIGN REVIEW DATA PACKAGE

The accumulated engineering data (which conforms to minimum project requirements on its technical content and format) is intended for careful study by the assigned technical specialists prior to a design review meeting

3.5 DESIGN REVIEW COMMITTEE

The appointed group of independent specialists whose recommended corrective measures are recorded during a design review meeting and entered into the minutes

3 6 PRESENTING ENGINEER

The engineer who acts as spokesman for the design (represented by the design review data package) and who is prepared to state the reasons for the selected design configuration and its detailed characteristics

3 7 DESIGN REVIEW NUMBER

A designation of the time phase of a given design review cycle with respect to the evolution of any product design Thus, there will be a first, second, and third design review for any given product design

3.7 1 Conceptual Design Review

The first (number 1) in a series of design reviews, conducted to verify the validity of the design concept in relation to established system constraints and criteria

3 7 2 Development Design Review

The second (number 2) in a series of design reviews, conducted to verify the validity of internal technical features of the design as disclosed by engineering studies and technical data

3 7 3 Preproduction Design Review

The third (number 3) in a series of design reviews, conducted to verify the completeness and accuracy of engineering data (drawings, specifications, etc) to be released to manufacturing

3.7 4 Contingent Design Reviews

Any design review conducted after design review number 3 and normally provided to (1) reassess design status after later testing phases (2) evaluate the effects of significant design modifications, or (3) conside: the suitability of a completed design for a new application

3 8 FORMAL DESIGN REVIEWS

A designation of the staging of design review meetings usually prescribed by customer requirements and often entailing attendance by customer representatives

3 9 SUBCONTRACTOR DESIGN REVIEW

A design review meeting conducted with the subcontractor normally assuming the data package and presenting engineer responsibilities and TRW Systems Group providing an attending customer representative

3.10 DESIGN REVIEW INSTIGATOR

The responsible TRW project or functional manager who authorize the conduct of a design review procedure and provides appropriate funding and schedule controls

4. DESIGN REVIEW RESPONSIBILITIES

4.1 PARTICIPANTS

The responsible participants and their assigned functions for any design review cycle are as outlined in Table 1 The responsibilities of the instigator and the design review staff are sustained throughout the complete implementation of design review cycles for each equipment and thereby provide continuity to the design review procedure The committee chairman, technical secretary, responsible engineer, presenting engineer, and committee members are appointed in accordance with Table 1 for a limited tenure as required to complete each of the required design review cycles

4.2 INSTIGATORS

a In the performance of internal design review functions, the instigator will be the product line manager (at laboratory level or above) responsible for the equipment involved

b In formal design reviews, the instigator will be the corresponding project manager

4.3 DESIGN REVIEW PLANNING

The instigator of design reviews, will plan for and control fiscal budgets in accordance with all design review requirements Three design review cycles (conceptual, development, and preproduction) will be provided for each equipment as a matter of standard policy. When conceptual design reviews are of sufficient technical depth to cover the conceptual factors of all included elements, repeated reviews at lower configuration levels will not be scheduled

Table 1 Responsibilities of Participants for Internal Design Reviews

Responsible Participant(s)		Design Review Function
Instigator	1	Authorization and funding of specific design review actions
Product Line Manager (Laboratory or above)	2	Establishes design rev ew master schedules and periodic updating
	3	Designates responsible engineer who has cognizance for the design to be submitted to design reviews
	4	Appoints committee chairman for each design review meeting
	5	Appoints to the design review committee senior design spec alist (i e with technical stature equ alent to that of the responsible engineer and/or presenting engineer)
	6	Approves disposition (i e acceptance or justified rejection) by the responsible engineer of each recorded recommendation of the design review committee
Committee Chairman	1	Presides over specific design review meeting(s) for which he is appointed
	2	Directs the transmittal of specific recommendations from the design review committee to the responsible engineer
	3	Directs the responsible engineer to implement design corrections before a prescribed time interval
	4	Directs the recording of action items in the course of design review meetings and assigns appropriate project funds and completion schedules
Member Design Review Staff	1	Provides a general procedure as a planning guide for design reviews
	2	Prepares specific design review procedures as requested by the instigator
	3	Provides means to account for all design review administrat ve con trols in behalf of the committee chairman
	4	Appoints participating committee members (other than the senior design specialists appointed by the instigator) in cooperation with the committee chairman and the instigator
	5	Instructs the respons ble engineer on the data package requirements as prescrib d in the applicable design revie procedure
	6	Provides the technical secretary to perform the follow ng functions to support of design review meetings
(Technical Secretary)		(a) Instruct the chairman committee members and other participants on the prescribed proceedings established in the applicable design review procedure
		(b) Take the minutes of design review meetings including design change recommendations and those action items which the chairman directs will be entered into the minutes
		(c) Document technical findings in the form of Agreements and cautionary comments in the form of Alerts into the minutes of design review meeting as found necessary
		(d) Prepare and issue action tem summaries and meeting min ites
Responsible Engineer	1	Directs and controls preparation of the design review data package in accordance with established procedure and schedule for the design review
	2	Provides for reproduction and distribution of the data package to all members of the design review committee its chairman and technical secretary
	3	Appoints the presenting engineer for each design review meeting
	4	Makes disposition of all design recommendations made by the design review committee and placed into the minutes by the chairman
Presenting Engineer	1	Makes oral briefings on the disclosed design in behalf of the responsi ble engineer
	2	An wers technical inquiries made by the members of the committee in both the course of data package analysis and design review meetings
	3	Participates in technical interchange at design review meetings and implementation of action items as assigned by the committee chairman
Committee Members		Provide d ata package ana ysis and attend design review meetings as specialists in their technical areas in conformance with the established schedule for a design review
	2	Complete data package analysis prior to the design review meeting and communicate with presenting engineer to clarify technical issues pursuant to data package analysis
	3	Provide in writing design recommendations based upon areas of technical specialty and present these proposals to the committee chairman at the time of the design review meeting
	4	Participate in technical interchange at design review meetings and implementation of action items as assigned by the committee chairman

4 4 FORMATION OF DESIGN REVIEW COMMITTEES

Design review committees will be formed to assure the scope of technical specialty prescribed by this design review general procedure in Table 2 This table prescribes the affiliation of each participant by whom he is designated and which design review number he is required tc attend

5 DESIGN REVIEW PROCEDURE

5 1 PRINCIPAL FACTORS

There are two related functions established and controlled by this general procedure (1) the engineering tasks necessary to complete a design review cycle and (2) the arrangements and recording tasks necessary to control design review cycles Figure A2-1 shows these factors for a representative design review cycle

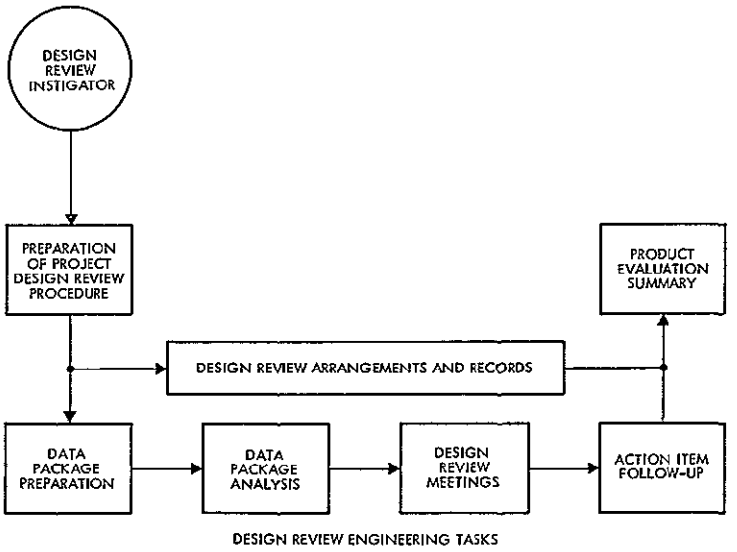

Figure B-1

BASIC ENGINEERING TASKS AND ARRANGEMENTS/RECORDS FOR RESIGN REVIEW CYCLES

5 2 ENGINEERING TASKS

5 2 1 Preparation of Project Design Review Procedure

The cognizant design review instigator will direct the design review staff to prepare individual design review procedures when required to augment this general procedure

Table 2 Participants in Design Review Meetings

	Assigned Responsibility	Participation Specialty		Affiliation	Designated By	Required for Design Review		
						#1	#2	#3
I	Presenting Engineer(s)	Spokesman for design disclosed in data package	Electrical circuitry	Unit engineer from Product Line Laboratory	Responsible engineer from Product Line Laboratory	X	X	X
			Mechanical design					
			Electronic packaging	Product engineer				
II	Design Review Committee	Meeting Chairman	Instigated by division	Product Line Laboratory	Instigator	X	X	X
			Instigated by other division	Project office				
		Senior design specialist(s) (one or two with stature equivalent to responsible engineer or presenting engineer		Outside of responsible Design Department	Instigator	X	X	X
		Member, design review staff			Design Review Staff	X	X	X
		Reliability analysis		Product Integrity Laboratory		X	X	X
		Electronic components (parts)					X	X
		Materials and processes					X	X
		Quality assurance						X
		Manufacturing		Hardware operations				X
		Value engineering		TRW Systems Product Assurance				X
III	Special Attendees	"On-Call" Support to Committee	Interfacint equipment	TRW departments maintaining specialty responsibility	Design Review Chairman	As designated in design review meeting notices		
			Mass properties					
			Thermal design					
			Magnetic properties					
			Support engineering					
			Other specialties					

The Design review staff member may serve as the technical secretary at design review meetings and functions as a committee member He reviews data packages and serves as participating specialist in the matters of

1 Conformance with stated company and division policies on design review

2 Interchange of design review experience (from other projects) by recognition of repetitive design-correction requirements

3 Assurance of combined effectiveness of product integrity support in parts, materials-processes and reliability

4 Conformance with requirements of TRW functional manuals for design-disclosure information (specifications, drawings, analyses, test data, etc)

5 2 2 Data Package Prepartion

Data package requirements will conform to the minimum conter shown (for each numbered design review and hardware subdivison) in Table 3

5.2 3 Data Package Analysis

Analysis of the design data given in the data package is the prin responsibility of the assigned committee members

5 2 3 1 Design Change Recommendations

Written recommendations for design change will be prepared by members of the design review committee during the course of data package analysis and brought to the design review meeting In the ev that a committee member submits no change recommendations to the chairman during the design review meeting, the minutes will docume his approval of the design as represented by the design review data package

5 2 4 Design Review Meetings

Requirements for the specific responsibilities of the chairman, technical secretary presenting engineer and the design review committee in their participation in design review meetings are as outline in Table 1 Meetings will be scheduled for a period sufficient to cove the planned agenda but preferable not longer than one (1) day per desi review cycle

5 2 5 Action Item Implementation

Design review cycles will be considered completed only when assigned action items have been completed by those to whom they are assigned and reported in accordance with paragraph 5 3 4 Action it identification and assignment will be provided by the chairman of each design review meeting Design review action items will be controlled as critical design requirements

5 2.6 Committee Approval Status

Approval of the design represented by the distributed data packa is contingent upon satisfactory completion of all assigned action items

Table 3 Design Review Data Package Requirements

	Technical Information X - Preliminary Y - Updated Z - Final	As normally provided in the course of equipment design	Design Review Cycle Number #1	#2	#3	Hardware Subdivision System	Subsystem	Major Component
1	Table of Contents for Data Package							
2	Requirements versus Capabilities							
	2 1	Operational Mission	Z			•	•	
	2 2	Mission Reliability and Apportionments	X	Y	Z	•	•	•
	2 3	Functional Modes and Characteristics	X	Y	Z	•	•	•
	2 4	Physical Characteristics (size, weight, c g , etc)	X	Y	Z	•	•	•
	2 5	Use of Resources (Power, Expendable Gas, etc)	X	Y	Z	•	•	•
	2 6	Environmental Extremes	X	Y	Z	•	•	•
3	Design Disclosure Data							
	3 1	Functional Flow (Block) Diagrams	X	Y	Z	•	•	•
	3 2	Equipment Specifications	X	Z			•	•
	3 3	Test Specifications		X	Z		•	•
	3 4	Fail-Safe and Redundancy Provisions		X	Z		•	•
	3 5	Assessed Reliability (Compared to Apportionment)		X	Z		•	•
	3 6	Drawings, Structural and Packaging		X	Z		•	•
	3 7	Drawings, Schematics		X	Z		•	•
	3 8	Measurements Data		X	Z		•	•
	3 9	Parts, Materials and Processes Lists		X	Z			•
	3 10	Qualification Test Data			X			•
4	Design Rationale							
	4 1	Trade-Off Analyses	X	Y		•	•	•
	4 2	Description of Alternate Designs		X	Y		•	•
	4 3	Interface Compatibility Analyses		X	Z		•	•
	4 4	Tolerance Accumulation Analyses		X	Z			•
	4 5	Use of Preferred Parts, Materials and Processes		X	Z			•

The data package for each design review should contain a matrix chart showing requirements versus capability for all essential design characteristics This chart should summarize the specification requirements for each design characteristic item, with the current assessment of proved capabilities as demonstrated by test data or analytical computations Each deficiency or indicated deficiency should be indicated on the matrix chart

and compliance with alerts and agreements entered into the minutes by the design review committee through the chairman

5 3 ARRANGEMENTS AND RECORDS

In support of each design review cycle, appropriate arrangements will be made and records kept by the design review staff (including the meeting technical secretary) to assure efficient participation of personnel and documented progress records These records will take the form of design review correspondence in the following areas

5 3.1 Meeting Notices

Based upon a master schedule of design reviews, established by the cognizant instigator, individual meeting notices will be prepared and distributed in conjunction with the distribution of the prescribed data packages to scheduled participants.

The meeting notices will designate the responsible meeting chairman technical secretary presenting engineer and committee members as well as any special attendees An agenda will be distributed with the meeting notices This agenda will outline the technical topics to be covered and their order of consideration. The responsibilities of committee members will be briefly restated in the meeting notice

5.3 2 Action Item Summary

As soon as practicable, after the adjournment of a design review meeting, a summary of action items recorded at the meeting will be distributed to all participants. The action item summary will show the precise action required, the name of the person assigned the task responsibility and a scheduled requirement date

5 3 3 Meeting Minutes

As soon as practicable, after the adjournment of a design review meeting, minutes of the design review meeting will be distributed In addition to assigned action items, the minutes will give a brief abstract of all firm committee recommendations during the technical proceedings These will include technical clarifications in the form of "Agreements" and cautionary comments or "Alerts "

5 3 4 Action Item Responses

Responses to action items will be made in writing by those to whom they were assigned They will be addressed to the chairman and the ESD Design Review Staff and maintained by the design review staff as an intergral part of the official record of the corresponding design review cycle

5 3 5 Action Item Status Reports

The status of action item responses will be periodically summarized by the design review staff to note items which are late in accordance with the scheduled requirements given in paragraph 5 4 These reports will be prepared periodically and addressed to the chairman and instigator

5.4 SCHEDULES

The specific calendar schedules for project design review meetings will be placed on the product line master schedule and adjusted to assure practical compliance with the following time-interval requirements

5 4 1 Minimum time scheduled for study of data package by committee members	5 working days
5 4 2 Maximum time duration for preparation and issuance of action item summaries	5 working days
5 4 3 Maximum time duration for preparation and issuance of meeting	10 working days
5.4 4 Maximum time duration for response to all assigned action items .	20 working days

6 TECHNICAL APPLICABILITY

6.1 PRINCIPAL PROJECT APPLICATIONS

This general procedure on design review is applicable to either hardware or software items Numbered design review cycles will be applied to software designs where effective

6 2 HARDWARE SUBDIVISIONS

Design review cycles will be scheduled for each major hardware subdivision of any system or subsystem Design review cycles will also be scheduled for meaningful groups of these system subdivisions to assure

effective design integration

6 2.1 System and Subsystem

Conceptual design reviews will be scheduled to validate the design at the highest level of assembly (viz subsystem or system) for which Electronic Systems Division has design responsibility Emphasis is placed upon the review of trade-off analyses and configuration decisions as based upon system level criteria and requirements System (or subsystem) level conceptual design review cycles will incorporate the conceptual analysis and review of the major components contained therein

6.2.2 Major Components

Development design reviews will be scheduled at intermediate design phases for each major component and at higher hardware levels when necessary to assure effective component integration Technical emphasis is placed upon the review of design trade-off of intra-component requirements and the study of design verification by laboratory testing

6 2.3 Lower Assembly Levels

Pre-production design reviews will be scheduled for each major component at the phase of development just prior to the release of final engineering drawings to Engineering Data Management and will incorporate detailed review of their lower assembly levels Emphasis will be placed upon the completeness and accuracy of the design-release data and upon the assurance of manufacturing-phase planning and efficiency

6 3 FUNCTIONAL SUBDIVISIONS

Within hardware subdivisions separate design review cycles or designated portions of design review meetings can be devoted to meaningful functional subdivisions For designs these functional subdivisions will, in general be restricted to (1) electrical circuit functions and (2) physical packaging functions. The scheduling of separate design review cycles or meetings for many functional subdivisions will be avoided to assure control of design review costs

6 4 CONTINGENT DESIGN REVIEWS

Where necessary, contingent design reviews will be planned and scheduled for hardware or functional subdivisions and will entail the

the same steps of design review procedure prescribed in paragraph 5 Such reviews must be initiated and funded by the instigator of this general procedure

6 5 SUBCONTRACTOR DESIGN REVIEWS

Design reviews for subcontracted design items will be planned scheduled, and coordinated by means of the procedural controls of paragraph 5, insofar as the subcontract provides. The technical findings from subcontractor design review cycles will be addressed to the design review staff for correlation with the design review results from the next higher level of assembly Product evaluation summary reports prepared by the design review staff will include all technical and status data obtained from subcontractor design review activities for the corresponding development project

7 AUTHORIZATIONS

The required design review documentation with corresponding authorizations are given in Table 4

TRW SYSTEMS

SUBCONTRACTOR RELIABILITY REQUIREMENTS FOR EARTH RESOURCES TECHNOLOGY SATELLITES

Approved by
P W Woodson
ERTS Performance Assurance

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REVISION STATUS SHEET

Revision	Date	Change	Signature

1.0 SCOPE

1.1 Objectives

The reliability disciplines contained within this plan are generated to be consistent with the requirements of NPC 250-1 These disciplines are applicable to all deliverable product end items of the ERTS Project as specified in the product specification The subcontractor is required to plan and implement a reliability program as an integral part of the design, development and production cycle

1 2 Application

This document is applicable to the extent specified in the Statement of Work

2 0 REFERENCED DOCUMENTS

NPC 250-1	Reliability Program Provisions for Space System Contractors
MIL-HDBK-217A	Reliability Stress and Failure Rate Data for Electronic Equipment

GSFC Preferred Parts List PPL-10

3 0 GENERAL REQUIREMENTS

3 1 Reliability Program

The subcontractor shall submit a preliminary reliability plan with his proposal and an updated plan in accordance with the requirements of the statement of work The subcontractor's reliability plan must be approved by TRW Systems In the case of conflict between the subcontractor's reliability plan and the requirements of this document, PAR-700-54 shall prevail

3 2 Reliability Requirements

The quantitative reliability requirements and demonstration of these requirements shall be as specified in the equipment specification

4 0 DETAILED REQUIREMENTS

The subcontractor's reliability plan shall acknowledge and indicate his meth of complying with the following detailed elements These elements are considered necessary to ensure the effective management and implementation of t overall reliability program

4 1 Reliability Organization

The reliability plan shall identify the organization and the key personnel responsible for implementing the overall reliability program

4 2 Reliability Analysis and Prediction

The reliability plan shall indicate the procedures to be followed in analyzing product reliability Detailed requirements for reliability analysis are as follows

4.2 1 Reliability Prediction

The reliability prediction shall include (1) a brief descripti of operation of the product, (2) a reliability mathematical model, (3) a reliability block diagram, (4) a schematic diagra (5) a temperature and electrical stress analysis (4 3 6 2) for each electronic part (to be used for adjusting the generic failure rates given in Appendix A) and (6) a predictio based on an orbital mission time of one year in orbit minimum and adjusted for the duty cycle of the equipment Reliability predictions shall be performed using methods approved by TRW Systems Basic electronic part failure rates listed in Appendix A shall be adjusted for actual use conditions in accordance with methods indicated in MIL-HDBK-217A Failure rates of items not listed shall be submitted to TRW Systems for approval

4 2 2 Failure Mode and Effects Analysis

The subcontractor shall perform and document Analyses of Failure Modes and Effects (FMEA) at the component level The analyses shall determine the possible modes of failure and their causes whereby the subcontractor's end-item could fail to perform its intended functions or meet failsafe requirements as defined by the product specification

4 3 Part Selection and Control

The subcontractor shall implement a program for part selection and control commensurate with the equipment reliability and functional life requirements Each part shall be controlled by a detailed specification which provides for compliance with the requirements listed below Copies of typical part specifications for each part type (transistors, ceramic capacitors, metal film resistors, etc) shall be provided to TRW Systems for review and approval

The parts program shall provide for the following

4 3 1 Part Selection

The subcontractor shall utilize in his deliverable equipment only parts with proven use and reliability histories for similar applications For flight equipment, parts should be selected in accordance with the following order of preference

ERMIL Established Reliability Military Specifications

JAN-TX Specifications for Semiconductor Devices

TRW or subcontractor high reliability specifications and standards

The subcontractor may use the TRW Systems document, M260618 titled, "Approved Parts List, Earth Resources Technology Satellite" as a guide This document will be made available to the subcontractor upon request

For the purpose of this document, for flight equipment, the above high reliability parts are defined as standard and all other electronic parts are defined as being non-standard Whenever the subcontractor elects to use a non-standard electronic part, he shall present to TRW Systems for approval his justification, the procurement specification, and other control/screening documents applicable

The selection and screening requirements for non-standard flight equipment parts shall be equivalent to those for the standard parts and in no event shall be less stringent than the requirements of Goddard Space Flight Center Preferred Parts List, PPL-1C TRW Systems approval will be required to utilize supplier high reliability programs

For ground equipment, the selection and application of parts shall, as a minimum, meet the applicable requirements of the GSFC Preferred Parts List, PPL-10

4 3 2 Non-Standard Parts Screening

All non-standard electronic parts used in the equipment delivered to TRW Systems must be subjected to a sequence of 100% (i e each part) screening tests as shown in Appendix B For electronic part not listed in Appendix B, TRW Systems' approval must be obtained prior to use

4 3 3 Part Traceability

The subcontractor shall comply with traceability requirements for all parts used within the deliverable equipment Traceabilit from a deliverable unit to a manufacturer's part processing lot (backward traceability) is required Criteria for lot definition shall be established in the procurement documentation Most ERMIL and JAN-TX specifications satisfy this requirement

Part serialization of critical items such as relays, crystals, switches, valves, and micro circuits should be considered to aid in selection where critical matching is required

4.3.4 Part Qualification

All electronic parts shall be qualified to environmental levels commensurate with related "MIL" specification limits for similar part types or with equipment environmental requirements, whichever is more severe Qualification tests shall include electrical, environmental, life, and mechanical testing in accordance with military specifications for similar parts

Qualification tests shall be performed on each lot of parts unless otherwise authorized by TRW Systems The subcontractor shall indicate in his program plan those parts considered qualified and the rationale, and shall present a plan to qualify the remainder Copies of the qualification test data shall be submitted to TRW Systems

4.3 5 Parts Standardization

The subcontractor shall review his equipment design for the purpose of reducing the number of part types and institute controls aimed at limiting the addition of new part types The TRW ERTS APL, M260 618, may be used as a guide

4 3 6 Parts Application

The subcontractor shall maintain and implement design guidelines for the application of electronic parts As a minimum, the subcontractor shall provide for the following

4 3 6 1 Parameter Variation

The subcontractor shall make allowances in his design for parameter variations of electronic parts These variations shall consist of end-of-life values as affected by time, temperature, and environmental conditions End-of-life values for standard parts will be supplied by TRW Systems to the subcontractor upon request for use as a guide

4.3 6 2 Part Derating

The subcontractor shall implement criteria for the derating of electronic parts appropriate with reliability requirements Derating to 25% of the manufacturer's recommended maximum is desirable for significant stresses such as dissipated power for semiconductors and resistors, voltage for capacitors and current for relays, contacts, inductors, and transformers

A part stress analysis shall be accomplished and maintained which indicates part rated stress, maximum operating stress and average stress for significant parameters such as voltage, current, dissipated power and operating temperature limits for each electronic part used in the equipment design These data will be reviewed at the design reviews prior to aporoval of design

4 Materials and Processes

The subcontractor shall establish a program for selecting, controlling and qualifying materials and processes which are used in his equipment design Each material and process shall be controlled by applicable specifications and procedures including those processes performed at outside facilities All materials and processes specifications shall be submitted to TRW Systems for review and approval

4 4 1 Material and Process Program

The subcontractor's reliability plan shall indicate the facilities and personnel available to support the material and process effort and indicate how these facilities and personnel will be employed to ensure an effective material and process program

4.4 2 Material and Process List

The subcontractor shall list all materials and processes and documentation controlling their procurement and application of (1) the material or process, (2) manufacturer, (3) manufacturer's description, (4) general description, (5) procurement specification, and (6) qualification status Documentation used to implement processes shall be available for TRW Systems' review This list must be updated periodically to reflect related changes in the design configuration

4 4.3 Material Traceability

The subcontractor shall comply with traceability requirements for all materials used within the deliverable equipment Traceability from a deliverable unit to the manufacturer's lot (backward traceability) is required

4 5 Failure Data Collection and Corrective Action

The subcontractor shall implement a failure reporting and corrective action system in accordance with the requirements listed below A failure is defined as any inability of a part, subassembly, component or function to perform in accordance with product specification requirements

4 5 1 Failure Reporting and Corrective Action System

The subcontractor shall implement a formal and controlled system for the reporting, analysis, corrective action, and data feedback of all failures and malfunctions which occur during all acceptance tests on deliverable products This system shall emphasize reporting, analysis and corrective action of all failures and malfunctions, regardless of their apparent magnitude The subcontractor shall accomplish timely and appropriate action to prevent recurrence of these failures and malfunctions The subcontractor's reliability organization shall review the procedures and monitor the implementation of this system The

subcontractor shall submit, as part of his reliability plan, sample copies of his failure reporting, failure analysis and corrective action formats

4.5.2 Failure Notification

The subcontractor shall report failures to TRW Systems no later than 48 hours after the failure event The TWX shall be address to the cognizant TRW Systems Contracts Administrator

4 5 3 Failure Reporting

The subcontractor shall document all failures as defined in 4 5 providing information to adequately describe the failed equipment, the operation in progress, the conditions of failure, the symptoms of failure, the action taken at the time of failure and the opinions of those who observed the failure as to the probable causes and possible methods of corrective action The failure report shall be transmitted automatically to the subcontractor's internal organizational elements affected and shall be filed for ready reference in a central location A copy of the failure report shall be sent to TRW Systems no later than 7 days after the occurrence of the failure

4 5 4 Failure Analysis

The subcontractor shall analyze all failures to determine the cause of each failure The failure analysis format shall reference the failure report and include a brief description of the actual failure, the methods of analysis and a technical description of the cause or causes In each case, the analysis shall be performed by or concurred with the organization responsible for the implementation of corrective action as delineated in 4 5 6 The subcontractor's reliability organization shall assur timely and accurate implementation of this task

4.5 5 Failure Analysis of Returned Equipment

The subcontractor shall analyze failed products returned by TRW Systems in the same manner as 4 5 4 TRW Systems will provide to the subcontractor the same type of failure information described in 4 5 3 for use by the subcontractor in his analysis If the analysis reveals the failure to be caused by external factors after delivery to TRW Systems, the subcontractor shall make recommendations for recurrence prevention If the analysis reveals causes under the control of the subcontractor or his suppliers, the subcontractor shall implement corrective action, as delineated in 4 5 6

4 5 6 Corrective Action

The subcontractor shall implement corrective action to prevent recurrence of failures when the analysis of 4 5 4 or 4 5 5 reveals the cause to be within his control The corrective action shall reference the failure report and the failure analysis The failure will be considered closed when corrective action is implemented and approved by TRW Systems The subcontractor's reliability organization shall assure the timely implementation of the necessary corrective action

The subcontractor shall review the results of corrective action after its implementation to assure adequate correction of the original problem and to assure that no other problems have been introduced Failure analysis and corrective action reports shall be submitted to TPW Systems no later than 30 days after failure occurrence

4 6 Design Review(s)

The subcontractor shall schedule and conduct formal design reviews in accordance with the statement of work For each design review, cognizant TRW Systems personnel shall be notified in advance and will participate as members of the reviewing group The design shall be reviewed for both

adequacy of conceptual approach and feasibility of simplifying design concepts The reviews shall cover materials, processes, electrical, mechanical, thermal and GDHS specification requirements, flow and logic diagrams, programming, test checkout, and compatibility interfaces. Existing failure histories shall be presented and reviewed for adequacy of the corrective actions to eliminate repetition of known failures Special design reviews may be scheduled by TRW Systems or the subcontractor as the need arises

4 6 1 Design Review Data Required

Data requirements for the design reviews are as shown in the Statement of Work The data shall form the basis for reviewing the design and must be submitted at the customer's facility, a minimum of ten (10) working days prior to the date of the design review

4 6 2 Design Review Minutes

Complete minutes of each design review meeting, giving details of discussion, conclusions reached, action items assigned, dates of completion, attendance, and similar pertinent information shall be submitted to TRW Systems in a design review report Design review action items which are not completed shall be reported through the periodic reliability progress report The subcontractor shall issue a subsequent design review completion report when the action items generated at each design review have been completed

4 7 Reliability Indoctrination and Training

The subcontractor shall initiate training for personnel, as necessary, to assure that their skills and knowledge keep pace with the advancing technology and that the errors due to the human element are minimized or eliminated The reliability training program shall be subject to TRW Systems audit

4 8 Monthly and Final Peports

The reliability program shall include the submission of monthly progress and final status reports These reports may be combined with other program documentation provided that all reliability information is contained or summarized in a separate report, or separate section of the monthly progress report, and supporting information is adequately cross-referenced and readily available The reports should provide a complete accounting of progress on each element defined by the program plan, results achieved, and status of actions to resolve major problems Failures and their respective corrective action and design review action items which have been completed shall be summarized in these reports Charts may be included which compare objectives, minimum requirements, predictions, and the level of achieved reliability for the system, subsystem and equipments

4 9 Reliability Audits

TRW Systems will notify the subcontractor prior to a periodic audit to ascertain the progress of the subcontractor reliability program

Appendix A

Electronic Part Failure Rate Table

Part Type	Failure Rate (30°C & 25% Rated Stress) Failures/10^9 Hours
Capacitors	
Ceramic	4
Filters, Feed-thru	10
Glass	3
Mica	20
Mlyar	20
Polystyrene	30
Tantalum, Foil	20
Tantalum, Solid	9
Variable	40
Connector pints, active	0 1
Connectors, Coax	10
Core, Magnetic	0.01
Crystals, quartz	20
Diodes	
4-Layer Devices (SCR, etc)	136
Silicon, General Purpose	3
Silicon Power Rectifier	44
Tunnel	100
Varactor	40
Zener	37
Inductors (per coil)	10

Part Type	Failure Rat (30° C & 25 Rated Stres Failures/10^9
Integrated Circuits	
Analog Amp	150
DTL	25
Hybird	150
MOS	100
RTL	25
TTL	50
Magnetic Amplifier	14
Relays, Latchnig	64
Relays, Non-latching	106
Resistors	
Carbon Comp	2
Metal Film	1
Wire Wound (Power, Precision, etc)	10
Variable, Wire Wound	50
Thin Film Resistor Network	50
Transformer	14
Transistors	
Field Effect	60
Silicon, High Power	40
Silicon, Low Power	10

SCREENING MATRIX TABULATION OF 100% TESTS

	IC's and Microelectronic Circuits	Transistors	Diodes	Comp Resistors	RF Switches, Mechanical	RF Switches, Solid State	Met Film Res	Variable Resistors	Magnetic Components	Wire Wound Res	Variable Capacitors	Relays	Capacitors - Plastic	Capacitors, Tantalum	Capacitors, Ceramic	Capacitors, Glass	Connectors	Quartz Crystals
Internal Visual Examination [1]	X	X	X		X	X					X	X					X	X[1]
High Temperature Storage	X	X	X			X												
Temperature Cycling	X	X	X		X	X	X	X	X		X	X	X					X
Acceleration	X	X	X															
Vibration					X	X					X	X						X[2]
Leak Test	X	X	X			X		X				X						X
100% Screening ( )=Min Burn-in Time-Hours	X 168	X 168	X 96	X[4] 148		X 168	X[6] 24	X[5] 100		X 100	X 168	X 6000 CYCLES	X 100	X 40	X 100	X[7] 50		X 30-Day Temp Cycle
Delidding Inspection[3]	X	X	X					X			X	X	X	X	X			X
(Receiving Inspection) (Parameter Testing)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Traceability - lot	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

NOTES (1) Pre-can or before paint on glass devices Min of 30X
(2) This test is done during electrical operation for crystals which must operate during launch.
(3) Sample destruct test
(4) 48 Hour Bake at 100°C, MIL-STD-202, Method 102A, Cond "D"
(5) Perform rotational cycling - 20 cycles
(6) Short-term overload with drift limits
(7) 3 to 5 times rated voltage

APPENDIX D

AN APPROACH TO RELIABILITY ASSESSMENT FOR COMPUTER PROGRAMS

1 INTRODUCTION

Software is one of three basic elementsof the Ground Data Handling System. The other two are automatic data processing equipment (hardware) and operations personnel. Software consists of the procedural and reference information that guides, directs, or controls the system whenever the system is operated. Typical software components are computer programs, data bases, and personnel instructions.

2. SCOPE

Pursuit of some fundamental reliability concepts applicable to the design, development, test, and operation of software is eased by temporarily concentrating on only one of the components above. This discussion centers primarily on computer programs and potential impact of a simplified reliability discipline on the computer program development cycle

3 DEFINITIONS

For purposes of this discussion "reliability" is defined as the "probability that a computer program will not fail to perform as required " "Maintenance" is the activity of detecting, isolating, and correcting failures either before or after their occurrence A failure is detected when it is determined that

- The design does not satisfy the requirements
- The computer program does not perform as specified by the design.

Efforts to cope with the above failure types has resulted in a formal design review program which is outlined in detail in other sections of this document.

Specific emphasis on the second failure type leads to some interesting concepts in reliability assessment of computer programs It is in relation to this assessment that the subtle characteristics of software become

extremely important and the subsequent emphasis on testing of the product must be established

4. APPROACH

Computer programs do not wear out, indeed the more they are used, the better they get "Better" here can be easily extrapolated to "more reliable" if a few conditions are met First, the use of the computer program must either methodically or haphazardly exercise more extensive portions of the program. That is, there is an experience factor or assessment ratio which is equivalent to the percentage actually encountered by the computer program of the total number of functionally distinct combinations of inputs and operating conditions specified. That percentage must increase with use Secondly, an analytical evaluation of that increased percentage, coupled with some meaningful characteristics of the individual computer program under consideration, can lead to a mathematical expression of increased confidence that the program will perform as required.

5. ASSUMPTIONS AND METHOD

A first approximation is made possible through use of available automated software test tools, one of which is specifically designed to assist in determination of several aspects of computer program usage at the instruction, subprogram, and program levels. An assumption which is fundamental to this simple approach to computer program reliability is that the increasing percentage of the computer program used (whether instructions exercised-vs-total instructions or some alternate ratio) is directly proportional to an increase in the value of the assessment ratio It is possible then to establish an approximate value for the probability that a computer program will not fail to perform under all conditions as required as the ratio (percentage) of the program "used" by the combination of all tests performed. Implicit in this evaluation is the assumption that failures incurred during use are corrected as necessary and will never recur (i.e., a sufficient maintenance activity is part of the program development). The reliability of a computer program, therefore, increases as it is used and as any failures are properly diagnosed and corrected.

6 CONCLUSIONS

Steps which have been identified as having most significant impact on the resulting reliability of computer programs are

- Modular design approach
- Use of "experienced" modules
- Independent construction to facilitate testing
- Conformance to approved standards and proven techniques
- Careful test planning and execution by an independent test organization.

All of these items are consistent with the single objective of attaining a minimum acceptable assessment ratio early in the design and development phases of program preparation and a guaranteed increase in that ratio throughout the entire software production cycle

APPENDIX E

PAR 700-55
13 FEBRUARY 1970

PROCUREMENT

PERFORMANCE ASSURANCE REQUIREMENTS

QUALITY, RELIABILITY AND MAINTAINABILITY PROVISIONS

PROJECT ERTS SUBCONTRACTORS

FOR

GDHS EQUIPMENT

Approved

J. K Holau, ERTS
Project Quality Manager

J. Pickavance, Manager
Space Vehicles Product Assurance

P W Woodson, Manager
Performance Assurance, ERTS Project

TRW
SYSTEMS GROUP

REVISION STATUS SHEET

Revision	Date	Change	Signature

PERFORMANCE ASSURANCE REQUIREMENTS
PROJECT ERTS GDHS EQUIPMENT

1.0 PURPOSE

1.1 To define the detailed TRW Systems Group Performance Assurance requirements to subcontractors of Ground Data Handling System (GDHS) equipment for the ERTS (Earth Resources Technology Satellite).

1.2 To provide subcontractors with the guidelines necessary to meet the basic quality, reliability and maintainability requirements of the subcontract for eventual equipment acceptance by the Government.

2.0 GENERAL REQUIREMENTS

2.1 The subcontractor shall provide and maintain an inspection system meeting all the requirements of NASA Quality Publication NPC 200-3, "Inspection System Provisions for Suppliers of Space Material, Parts, Components and Services", dated April 1962, except as amended herein

2.2 In addition to the requirements of this document, PAR 700-55, the subcontractor shall meet the supplemental quality, reliability and maintainability requirements to this document and the requirements of the supplemental clauses of TRW Systems Form 1991, "Supplier Quality Attachment I to SQI 3.0.3", when these clauses are specified on the purchase order/subcontracts.

2.3 When the subcontractor determines that certain requirements of this document are deemed not pertinent to his subcontract, request for clarification and/or deletion should be made to TRW Systems Group. Mil-spec and off-the-shelf (existing catalog) items are exempt from the NPC 200-3 requirements.

3.0 AMENDMENTS TO NPC 200-3

3.1 Preparation and Submission of Suppliers' Inspection Plan NPC 200-3, Section 2.2

The subcontractor shall submit three (3) copies of a written inspection plan to TRW Systems Group for approval within thirty (30) days after purchase order award. The format of the subcontractors' plan shall be in substantial accordance with each section heading of NPC 200-3 and the additional requirements of this document.

3.2 Drawing and Change Control (NPC 200-3, Section 2.4)

3.2.1 General

The subcontractor must maintain a system for implementing, recording and verifying changes in product configuration at specified change effectivity points. When design is the subcontractor's responsibility, but design changes require TRW approval prior to incorporation and/or production, Class I changes shall not be made in design or manufacture without the written approval of TRW.

3.2.2 Design Review(s)

The subcontractor shall schedule and conduct formal design reviews in accordance with the statement of work. For each design review, cognizant TRW Systems personnel shall be notified in advance and will participate as members of the reviewing group. The design shall be reviewed for both adequacy of conceptual

approach and feasibility of simplifying design concepts and shall consider quality, reliability and maintainability requirements. The reviews shall cover materials, processes, electrical, mechanical, thermal and GDHS specification requirements, flow and logic diagrams, programming, test checkout, and compatibility interfaces. Existing failure histories shall be presented and reviewed for adequacy of the corrective actions to eliminate repetition of known failures. Special design reviews may be scheduled by TRW Systems or the subcontractor as the need arises

3.2.2.1 Design Review Data Required

Data requirements for the design reviews are as shown in the Statement of Work. The data shall form the basis for reviewing the design and must be submitted at the customer's facility, a minimum of ten (10) working days prior to the date of the design review

3.2.2.2 Design Review Minutes

Complete minutes of each design review meeting giving details of discussion, conclusions reached, actions items assigned, dates of completion, attendance, and similar pertinent information shall be submitted to TRW Systems in a design review report Design review action items which are not completed shall be reported through the periodic progress report. The subcontractor shall issue a subsequent design review completion report when the action items generated at each design review have been completed.

3.3 Government Source Inspection (NPC 200-3, Section 3.2)

When the purchase order specifies Government Source Inspection required, all work is subject to inspection and test monitoring by the Government representative. Notification should be in advance of the inspection and/or test operation at a time mutually agreed.

Delegation of Material Review Board authority to the Government representative that normally services the subcontractor's plant though not normally granted (para 3.6), shall be at the discretion of the responsible Government agency for this contract.

3.4 Control of Materials (NPC 200-3, Section 3.5)

Raw materials, materials, and products shall be inspected to determine conformance to applicable specifications and drawings and acceptability for use on deliverable equipment. Where appropriate, the subcontractor may use GSFC Preferred Parts List PPL-10 as a guide for electronic part selection and control.

3.5 Inspections and Tests (NPC 200-3, Section 3.6)

The inspections and test performed shall include in addition to the NPC 200-3 requirements, the qualification and acceptance testing of software, the integration of the hardware and software at the site using engineered stimuli to simulate operating conditions, and the performance of the system during observatory orbital operations.

3.6 Nonconforming Articles (NPC 200-3, Section 3.8)

TRW Systems Group will normally not delegate material review authority to its subcontractors, who may perform preliminary reviews and make dispositions in accordance with the provisions of Section 3.8. If a major subcontractor to TRW has design cognizance, he may request authority to establish a formal Material Review Board for purposes of making dispositions on materials or products on which variations exist. Deviations can only be dispositioned b NASA by means of a request for contractual waiver. The granting of variation materials review authority by TRW is contingent upon concurrence by TRW's customer and the cognizant Government inspection agency. For purpose of this document, variation and deviation are defined as follows

- "Variation" Any nonconformance to drawing or specification requirements which, in the opinion of TRW Systems Group Quality Assurance does adversely affect safety, interchangeability, service life, reliability or performance.
- "Deviation" Any nonconformance to drawing or specification requirements which, in the opinion of TRW Systems Group Quality Assurance does adversely affect safety, interchangeab_lity, service life, reliability, performance, or the basic requirements of the contract.

If a major subcontractor wishes to request variation material review authority from TRW Systems Group, he must submit the following to TRW Systems Group Quality Assurance via TRW Systems Group Materiel. Complete documentation of the proposed Material Review Board organization and the policy under which the board proposes to operate This documentation must include

- Organization chart(s) showing the line authority of all proposed engineering and Quality personnel involved.
- Complete resumes of proposed personnel, showing their backgrounds, experience, education, etc.
- Copies of proposed detailed operating procedures
- Copies of all proposed forms, tags, etc., and a description of their usage.
- Complete description of the cause investigation and corrective action system the subcontractor proposes to use to prevent the recurrence of all variations that the proposed board will review disposition.

When a subcontractor is approved to conduct a formal material review on variation, TRW Systems Group reserves the right to reject the decision of the subcontractor's Material Review Board; additionally, TRW reserves the right to reject materials or products covered by such decisions after delivery at

a TRW Systems Group facility, or the installation site. The subcontractor's cognizant Government Quality Assurance representative must approve all decisions made by the other two members of the subcontractor's Material Review Board. The subcontractor's Material Review Board can make the following decisions

- Scrap Any one (1) member of the board may make a scrap decision without the concurrence of the other two (2) members.
- Reject (Return to Vendor) Any one (1) member of the board may make a reject decision without the concurrence of the other members.
- Rework to Specification If the nature of proposed rework is minor, and does not require engineering action, the decision to rework may be made by the quality member of the board. Major rework requires engineering members concurrence.
- Rework Beyond Specification This decision requires concurrence of all members of the board. At the time this decision is made, it must be decided whether the extent beyond specification constitutes a variation or a deviation, this decision requires the concurrence of

all members of the board, as a deviation cannot be accepted.

Use As Is This decision requires concurrence of all members of the board. NOTE Deviations cannot be accepted by Material Review Board.

3.7 Control of Inspection Measuring and Test Equipment (NPC 200-3, Section 3.0)

The calibration of measuring and test equipment must be in conformity with MIL-C-45662A.

3.8 Records of Inspections and Tests (NPC 200-3, Section 3.13)

An end-item inspection and test report shall be prepared and transmitted with the subcontract end-item and shall include the following

- End-item configuration list
- End-item nonconformance record
- Copy of end-item systems acceptance test reports or procedures which include variables test data and results
- List of critical and time/temperature sensitive articles
- Operating time/cycle record of system and subsystem, where applicable.
- Final assembly build-up and test procedure, including end-item test article replacements.

Records of all inspections and tests shall be made available to TRW Systems Group for review when requested.

4.0 ADDITIONAL REQUIREMENTS

4.1 TRW Systems Group Source Surveillance

Periodic audits may be made by TRW Systems Group Quality Assurance in coordination with Materiel during the life of the purchase order to determine compliance with this document and the extent to which the specified procedures are being followed by the subcontractor. Upon completion of the audit, the subcontractor will be notified in writing of those areas requiring correction. The subcontractor will be given an appropriate period of time within contractual limits to correct deficiences.

TRW Systems Group Quality Assurance reserves the right to interpret the extent to which this document applies on supplies and services for each subcontract.

TRW Systems Group may assign resident or itinerant Engineering/ Quality Assurance personnel to the subcontractor's facility during performance of the subcontract. The subcontractor must, during regular business hours, or at such other time as may be necessary, permit such personnel access to his facilities for determination of compliance with this document and must furnish without cost to TRW Systems Group such facilities and services which may reasonably be required in support thereof.

4.2 Indoctrination and Training.

The subcontractor shall institute a training program for personnel, as necessary, to operate the deliverable system to assure that their skills and knowledge keep pace with the advancing technology, and to minimize or eliminate the errors due to the human element. The training program shall be subject to TRW Systems audit.

4.3 Failure Data Collection and Corrective Action

The subcontractor shall implement a failure reporting and corrective action system in accordance with the requirements listed below. A failure is defined as any inability of a part, subassembly, component or function to perform in accordance with product specification requirements.

4.3.1 Failure Reporting and Corrective Action System

The subcontractor shall implement a formal and controlled system for the reporting, analysis, corrective action, and data feedback of all failures and malfunctions which occur during system integration and operational tests performed after equipment installation on-site. This system shall emphasize reporting, analysis and corrective action of all failures and malfunctions, regardless of their apparent magnitude. The subcontractor shall accomplish timely and appropriate action to prevent recurrence of these failures and malfunctions. The subcontractor's reliability organization shall review the procedures and monitor the implementation of this system.

4.3.2 Failure Notification

The subcontractor shall report failures to TRW Systems no later than 48 hours after the failure event. The TWX shall be addressed to the cognizant TRW Systems Contracts Administrator.

4 3.3 Failure Reporting

The subcontractor shall document all failures as defined in 4 3 providing information to adequately describe the failed item, the operation in progress, the conditions of failure, the symptoms of failure, the action taken at the time of failure and the opinions of those who observed the failure as to the probable causes and possible methods of corrective action. The failure report shall be transmitted automatically to the subcontractor's internal organizational elements affected and shall be filed for ready reference in a central location. A copy of the failure report shall be sent to TRW Systems no later than 7 days after the occurrence of the failure.

4.3.4 Failure Analysis

The subcontractor shall analyze all failures to determine the cause of each failure The failure analysis format shall reference the failure report and include a brief description of the actual failure, the methods of analysis and a technical description of the cause or causes. In each case, the analysis shall be performed by or concurred with the organization responsible for the implementation of corrective action.

4.4 Maintainability Analysis

The subcontractor shall perform a maintainability analysis of the GDHS equipment and define in detail the activities, support documentation, personnel and equipment required to perform each corrective and preventative maintenance task associated with the servicing of the GDHS hardware. The significant failure modes of each hardware end-item shall be identified together with an estimate of the frequency (failure rate) that each may be expected to experience in an operational environment, the unwanted effects that can occur in the event of each sub-assembly failure mode, and the method of failure recognition and fault isolation utilizing equipment monitors and controls. In addition, for each such failure mode, a maintenance concept shall be described which shall include the type of personnel and equipment which are necessary to effect a repair or replacement in a timely manner together with an estimate of the average length of time (Mean-Time-To-Repair, MTTR) needed to complete the repair action and return the item to operational status. This includes considerations for emergency corrective measures.

The latter time shall also include specific recommendations for equipment checkout and status verification required to assure that the repair is effective. Recommendations for each hardware end-item shall also be made in the areas of scheduled maintenance and sparing levels. The rationale for determining the frequency and duration of scheduled maintenance periods shall be provided, similar data concerning recommended spares packages or kits shall also be provided, the objective being the identification of a spares package which will reduce the

likelihood of running out of spares in a cost-effective manner. These analysis tasks will utilize data gathered on previous applications of similar equipments to the maximum possible extent. The above analysis task shall be performed and presented for each design review and updated as necessary throughout the program. Submittal of the final analysis report will be made at the conclusion of the 30 day operational performance period for the GDHS.

4.4.1 Operating Time Logs

Operating time logs will be maintained for each unit during periods for which failure reporting is required to evaluate the accuracy of previously derived analytic projections. Elapsed time meters, sign-in, sign-out sheets, or other workable procedures shall be employed to ensure that the starts, stops and operational times for the hardware items are accurately kept. The duration of time required to complete any maintenance action shall be noted together with some assessment as to whether the repair effected was in accordance with the method projected in the maintainability analysis. Unusual conditions which are felt to be non-typical shall be identified.